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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 189

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ April 12, 1915

STUDIES OF THE CODLING MOTH IN THE CENTRAL APPALACHIAN REGION

By

F. E. BROOKS and E. B. BLAKESLEE, Entomological Assistants
Deciduous Fruit Insect Investigations

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By F. E. Brooks and E. B. Blakeslee,
Entomological Assistants, Deciduous Fruit Insect Investigations, Bureau of Entomology.

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INTRODUCTION.

In many localities throughout the central Appalachian region the recent rapid development of the apple-growing industry has made the control of the codling moth (*Carpocapsa pomonella* L.) a subject of special and increasing interest. The hilly or mountainous nature of the land has led to the location of orchards at elevations ranging from a few hundred feet to more than 4,000 feet above the level of the sea. The great diversity of temperature that occurs between the lower and the more elevated orchards has a marked effect on the time of transformation of the different stages of the codling moth, and consequently has direct bearing on the relative number and the destructiveness of second-brood larvæ.

In the spring of 1911 the Bureau of Entomology began a study of the codling moth in the region just mentioned, as a part of its inves-

tigations of this insect throughout the United States, giving particular attention to time of appearance of the different broods at various altitudes and latitudes. The work was conducted by or under the immediate direction of the authors of this paper and was continued for three consecutive years at several points located in Virginia, West Virginia, and Maryland.

The writers are greatly indebted to the large number of fruit growers in the various localities where the investigations were carried on for the free use of orchards in which to obtain banding records, for buildings to shelter rearing jars, and for other courtesies. During the progress of the work many essential suggestions were made by Prof. A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations, under whose direction the studies were made.

LOCALITIES IN WHICH INVESTIGATIONS WERE MADE.

The studies described herein were conducted at Charlottesville, Fishersville, Greenwood, and Winchester, Va.; Keyser, French Creek, and Pickens, W. Va.; and Hagerstown, Smithsburg, and Hancock, Md. The senior author had charge of the investigations in West Virginia and the junior author had charge in Virginia and Maryland. At several of the points mentioned only partial or incomplete records were obtained. The similarity of conditions at Smithsburg and Hancock, Md., and Keyser, W. Va., to other localities where records were being kept, together with a shortage of the fruit crop and the difficulty of visiting so many places at sufficiently frequent intervals, led to the discontinuance of operations at these points after the first year.

NATURE AND EXTENT OF THE INVESTIGATIONS.

The work was conducted by selecting, for banding, from 10 to 15 unsprayed bearing apple trees of late ripening varieties in each locality. Wherever it was possible medium-sized trees with smooth bark were chosen. In some cases such trees could not be found and old trees with rough bark were used. The rough scales of bark were scraped from the trunks and from the bases of the larger branches of these old trees, but even then they were much less desirable for the purpose than the younger, smooth-barked trees.

In the spring, before the first-brood codling-moth larvæ had commenced to leave the fruit, burlap bands were tied around the trunks of the trees 2 or 3 feet above the ground, and in some cases additional bands of the same material were placed around the bases of the larger branches. The trees were all tagged and an individual account kept as to the number of larvæ going under the bands to "spin up." The bands were removed and examined at frequent intervals and the

larvæ taken from them were counted and placed in rearing jars. In 1911 the larvæ were collected and the rearing jars examined every 10 or 12 days, and in 1912 and 1913 the examinations were made every 3 or 4 days. During the course of the work more than 20,000 larvæ were collected and placed in the jars for rearing.

The jars containing the larvæ were supplied with small devices made of thin pieces of wood bound together, with openings between into which the larvæ entered to "spin up." It was found that strips cut from sheets of transparent celluloid could be used under the wood to advantage, as this permitted the wood covering to be removed for the purpose of examining the larvæ or pupæ without tearing or disarranging the cocoon. The jars were covered with cheesecloth and were placed under shelter, usually in open sheds, where they had out-of-door temperature. These sheds were always located near the orchard in which the larvæ had been collected. The jars were examined on the same dates as the bands, and the moths that had issued at each examination were counted and destroyed. Larvæ that wintered were preserved and records were made of the date they issued as moths the spring following. So far as possible the band records were checked and supplemented by observations on the condition of the insect in the orchard.

EXPLANATION OF THE USE OF TERMS.

The terminology of this paper is made to conform as nearly as possible with that of previous papers on the codling moth issued by the bureau. The term "generation" applies to the moth in all its stages from the egg to the adult, regardless of whether the life cycle is completed in one season or whether the insect winters during its development, in which case the life cycle would occupy parts of two seasons. The term "brood" is used to designate the insect in any of its four stages. Broods of eggs, larvæ, pupæ, and imagos occur normally, with more or less seasonal regularity, in the orchards of any given locality, and the term "brood" usually refers to the individuals in the aggregate of any particular stage of a given generation.

In the Appalachian section a first brood and a partial, or practically full, second brood of larvæ occur annually. In some southern localities a small third brood is possible. Some of the larvæ of the first brood and practically all those of the second brood winter in the cocoon. These are all spoken of as "wintering larvæ." In the spring these wintering larvæ transform to "spring pupæ," which in turn develop into "spring moths." The spring-brood moths produce "first-brood eggs," from which hatch "first-brood larvæ." The individuals of this generation that complete their transformation during the first season are known in their successive stages as "first-brood

pupæ" and "first-brood moths." These moths in turn produce "second-brood eggs" and "second-brood larvæ." Where "second-brood pupæ" and "second-brood moths" occur they may produce "third-brood eggs" and "third-brood larvæ."

INVESTIGATIONS AT CHARLOTTESVILLE, VA.

DESCRIPTION OF LOCALITY.

Charlottesville is situated at the foot of the eastern slope of the Blue Ridge Mountains, at an elevation of 400 to 500 feet above sea level. In the immediate vicinity of the city there are several large and profitable bearing apple orchards, as well as a considerable acreage of young orchards planted within the last four or five years. Its own interests, therefore, as well as its proximity to the large orchards of the Blue Ridge section, make Charlottesville of considerable importance as a commercial apple-growing center. Investigations of the seasonal life history of the codling moth were carried on in this section in 1911, 1912, and 1913. Only the work of the last two years, however, was considered of sufficient value to be included in this report.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

A large proportion of the larvæ collected in the orchard in the fall of 1911 succumbed to cold or disease the following winter, and the rearing material available for moth emergence was consequently rather limited. On account of the small number of insects reared and some irregularity in the observations the records are not included in detail. Moths were first observed in the rearing cages at Charlottesville on May 7, and at Greenwood, where conditions are not far from those at Charlottesville, adults began appearing about May 8. Also the summer brood of moths emerged in the rearing cages at Charlottesville 45 days later (June 20), which is about the interval that must elapse between the two broods of adults in that latitude. Therefore we may safely assume that in 1912 the emergence of spring-brood moths began in the orchards at Charlottesville soon after May 1.

FIRST-BROOD MOTHS.

Table I gives the time of emergence of 247 moths that issued from band-collected material at Charlottesville in 1912. Beginning on June 20, emergence continued through the rest of June, the whole of July, and about half of August. One moth emerged as late as September 2.

TABLE I.—*Emergence of first-brood moths of the codling moth at Charlottesville, Va., in 1912.* (See fig. 1.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 20	1	Aug. 1	5
24	5	5	10
28	32	9	30
July 2	1	13	20
5	42	17	7
10	6	21	3
13	22	25	0
17	15	29	0
21	23	Sept. 2	1
25	12		
29	12	Total	247

BAND COLLECTIONS.

It would be difficult to find a more satisfactory orchard in which to conduct band-record experiments than the one used at Charlottesville in the summer of 1912. The trees used were part of an orchard

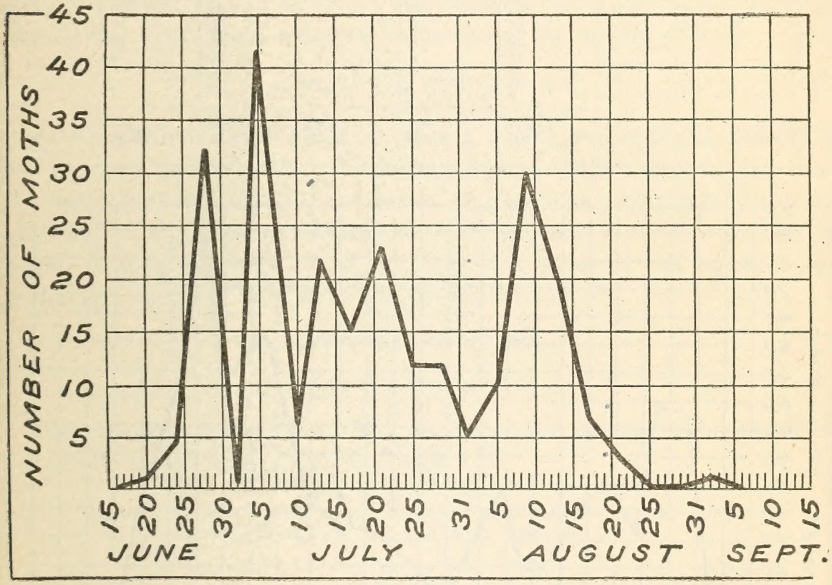

FIG. 1.—Diagram to illustrate emergence of first-brood moths of the codling moth (*Carpocapsa pomonella*) at Charlottesville, Va., in 1912.

that had not been sprayed for a number of years. Those banded were of the Winesap variety, about 18 years old, and carried a heavy crop of fruit throughout the season. In Table II are given the collections of the season and the summarized results of the rearing experiments.

TABLE II.—*Number of larvæ of the codling moth taken from the bands and reared at Charlottesville, Va., in the summer of 1912 and the spring of 1913.* (See fig. 2.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1912.	Number overwintering.	Number winter-killed.	Number of moths emerging, 1913.
June 12	12	.....	12	.....	.....	.....
17	48	14	34	.....	.....	.....
22	49	11	38	.....	.....	.....
26	26	8	18	.....	.....	.....
July 1	34	11	21	2	2	.....
5	33	10	23	.....	.....	.....
9	26	9	17	.....	.....	.....
13	20	2	17	1	.....	1
17	20	1	19	.....	.....	.....
21	34	12	22	.....	.....	.....
25	27	11	15	1	.....	1
Aug. 1	12	.....	4	8	2	6
5	20	.....	5	15	.....	15
10	23	1	1	21	2	19
13	26	3	.....	23	3	20
17	27	.....	.....	27	.....	27
21	37	10	1	26	16	10
25	30	.....	.....	30	15	15
29	45	10	.....	35	15	20
Sept. 2	61	7	.....	54	28	26
5	60	6	.....	54	13	41
10	52	9	.....	43	.....	43
14	80	20	.....	60	5	55
18	53	2	.....	51	19	32
25	32	3	.....	29	13	16
29	14	4	.....	10	4	6
Oct. 2	2	.....	.....	2	.....	2
5	2	.....	.....	2	2	.....
Total	905	164	247	494	139	335
Per cent	100	18.12	27.29	54.59	15.36	39.23

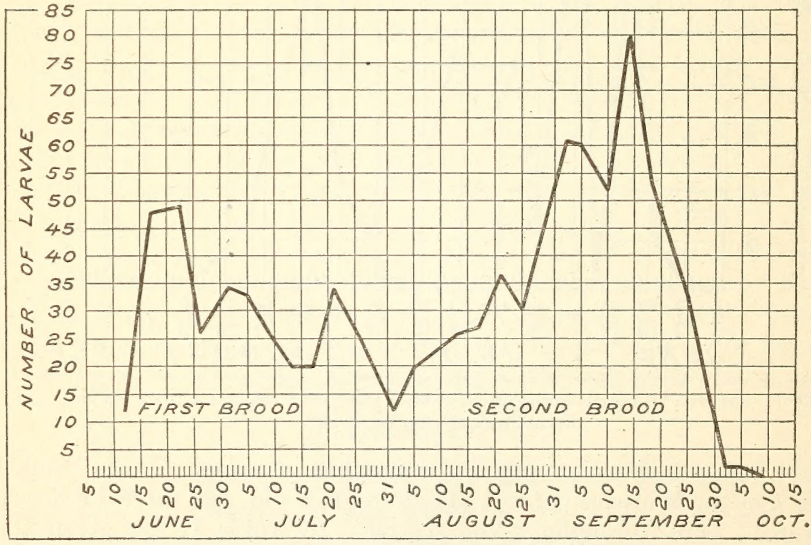

FIG. 2.—Diagram to illustrate band collections of larvæ of the codling moth at Charlottesville, Va., in 1912.

Unfortunately examinations were not begun until June 12, while larvæ were doubtless leaving the fruit as early as June 5–6. Codling-

moth larvæ appeared under the bands in considerable number throughout June and July, most of those collected previous to August 1 transforming to adults the same season. After August 1 the number of larvæ collected again increased considerably, the greater part of those taken after this date spinning up and wintering. Since summer-brood moths appeared June 20, it is reasonable to suppose that second-brood larvæ were beginning to enter the apples about July 1. If we allow a slightly longer time than has been found by other observers to be the minimum feeding period of the second brood, we might expect second-brood larvæ to be leaving the fruit by the last of July to the first of August. The fruit was picked shortly after October 5 and the records discontinued, although a few of the second brood had not finished feeding by that time.

Table II gives the results of the rearing experiments carried on with the 905 larvæ taken in the orchard in the summer of 1912. Due to handling, cannibalism, disease, etc., 18.12 per cent were lost in the rearing jars; 27.29 per cent emerged as moths that season; 54.59 per cent wintered; 15.36 per cent were winter-killed; and 39.23 per cent passed the winter and emerged as moths in the spring of 1913.

SUMMARY FOR SEASON OF 1912.

At Charlottesville in 1912 the spring-brood moths began emerging in the early part of May. First-brood larvæ began leaving the fruit the early part of June. First-brood moths began emerging June 20, allowing 10 days for egg-laying and incubation; second-brood larvæ began feeding by July 1. After August 1 most of the larvæ taken under the bands belonged to the second brood.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

The emergence records of 355 moths of the spring brood at Charlottesville in 1913 are given in Table III.

TABLE III.—*Emergence of spring-brood moths of the codling moth at Charlottesville, Va., in 1913.* (See fig. 3.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
Apr. 18	2	May 21	21
21	2	24	21
24	2	27	11
27	7	30	10
30	18	June 2	8
May 3	78	5	8
6	27	8	1
9	42	11	1
12	17		
15	55	Total	355
18	24		

It will be remembered that the work of 1912 did not include a detailed account of the appearance of the spring brood. There was, however, very good evidence that spring-brood emergence began that season shortly after May 1. On the whole the seasonal conditions of the spring of 1913 were slightly in advance of those of 1912, and spring-brood moth emergence seems to have occurred about 10 days earlier in the former year. Moths began appearing in numbers on April 27–30, and maximum emergence was reached on May 3. Moths continued to issue in jars through May and part of June, emergence ceasing June 11. It is probable that first-brood larvæ began feeding by May 1, or 12 days after the first moth appeared in the rearing cages.

FIRST-BROOD MOTHS.

In 1913 the first of the first brood or summer brood of moths issued on June 14, from material taken under the bands in the orchard on June 5. However, emergence occurred in numbers on June 23 and reached its maximum on July 8. On the whole the graph in figure 3 probably represents fairly well the time of appearance in the orchard of the two broods of moths at Charlottesville in 1913. An occasional second-brood larva may have begun feeding by June 25, but it is probable that the insects were not entering the fruit in numbers before July 1.

TABLE IV.—*Emergence of first-brood moths of the codling moth at Charlottesville, Va., in 1913.* (See fig. 3.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 14	1	July 23	7
17	3	26	7
20	5	29	16
23	18	Aug. 1	7
26	11	4	2
30	24	7	2
July 2	26	10	0
5	26	13	3
8	40	16	1
11	21	19	0
14	28	22	1
17	10		
20	11	Total	270

BAND COLLECTIONS.

At Charlottesville, as in the other parts of the central Appalachian section, the short crop of fruit during the season of 1913 seriously interfered with the work. After the dropping, which normally follows the feeding of the first brood, not enough fruit remained to furnish food for the second-brood larvæ, and the unusually small numbers of larvæ that appeared under the bands in the latter part of the summer throw out of line completely the proportions of transforming and wintering insects. The relatively small number of overwintering larvæ given in Table V must be considered as unusual and not as evidence of what occurs under normal conditions.

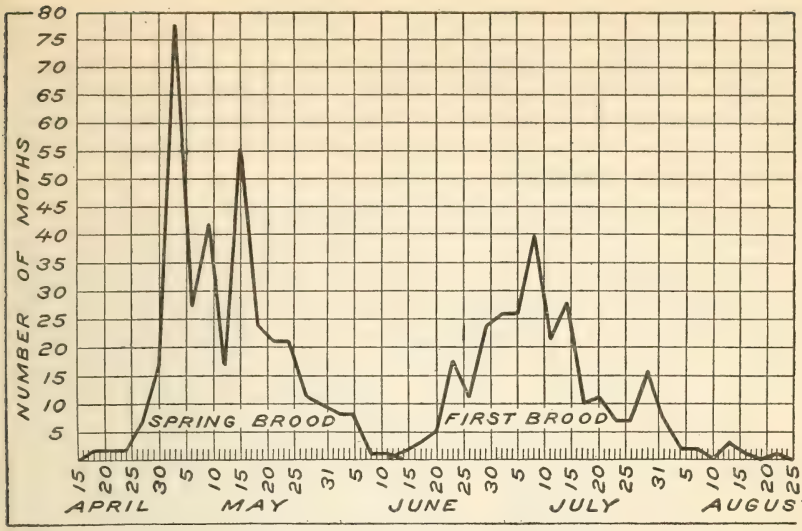

FIG. 3.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Charlottesville, Va., in 1913.

TABLE V.—*Number of larvæ of the codling moth taken from bands and reared at Charlottesville, Va., in 1913.* (See fig. 4.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1913.	Number of larvæ overwintering.
June 5	6	2	4	
8	20	7	13	
11	33	11	22	
14	18	5	13	
17	35	19	16	
20	90	32	57	1
23	37	10	27	
26	54	27	25	2
30	85	52	31	2
July 2	19	8	9	2
5	23	3	20	
8	15	7	8	
11	10	4	5	1
14	8	3	4	1
17	10	3	7	
20	3	2	1	
23	1		1	
26	5		5	
29	1		1	
Aug. 1	2	1		1
4	13	10		3
7	3			3
10	1	1		
13	8	3	1	4
16	3	1		2
19	6	1		5
22	3	1		2
25	2			2
28	9	5		4
Sept. 1	1			1
3	1			1
6	5	1		4
9	2			2
12				
15	10	4		6
Total	542	223	270	49
Per cent	100	41.14	49.82	9.04

First-brood larvæ were taken from the bands on June 5, and continued to appear in increasing numbers through the remainder of June and most of July, the largest collection of the season occurring on June 20. Since moths of the summer or first brood appeared in the rearing cages on June 14 and in numbers by June 20, second-brood larvæ were probably entering the fruit in the field June 25–30, and, allowing a normal feeding period, must have begun to appear under the bands in the last of July to the first of August. A few larvæ were collected up to September 15, when the remaining fruit was picked and the records discontinued. Figure 4 represents graphically the numbers and time of collection of the larvæ taken from the bands during the season. In all, 542 larvæ were taken from the bands, 223,

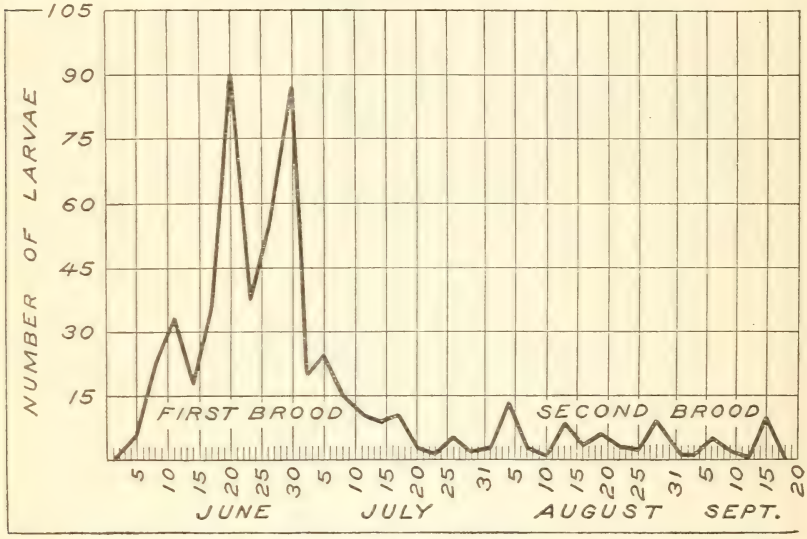

FIG. 4.—Diagram to illustrate band collections of larvæ of the codling moth at Charlottesville, Va., in 1913.

or 41.14 per cent, of which perished in the rearing cages; 49.82 per cent emerged as moths the same season, while 9.14 per cent spun up and wintered. As has already been explained, the comparative numbers of wintering and transforming larvæ given in Table V must not be considered usual. At Charlottesville in an ordinary season a large proportion of the first brood transforms, giving rise to a relatively large second brood, and with a fair crop of fruit the larvæ of the second brood taken under the bands should far exceed the first in numbers.

SUMMARY FOR SEASON OF 1913.

Spring-brood moths began emerging at Charlottesville on April 18. First-brood larvæ might be expected to have entered the fruit by April 28–30, though not in any number until several days later.

First-brood larvæ were taken under the bands June 5, and by August 1 probably most of them had left the fruit. First-brood moths appeared in the rearing cages on June 14, and in numbers June 23. Second-brood larvæ must have been entering fruit June 25–30, and were leaving by the last of July to the first of August.

INVESTIGATIONS AT GREENWOOD, VA.

DESCRIPTION OF LOCALITY.

Greenwood is situated about 18 miles west of Charlottesville, in a section of the Blue Ridge Mountains where commercial apple growing has been well established for years. In a mountain orchard section, such as this, there is considerable variation in the elevation of orchard sites. The orchard in which band-record experiments were conducted was at an altitude of about 900 feet above sea level. The work in this section for the season of 1912 is given in part only, the moth emergence of that summer being considered of sufficient importance to find a place in this report.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

Table VI contains the emergence records of 180 moths as they occurred in the rearing cages at Greenwood in 1912. The first visit of the season to Greenwood was made on May 8, and the table shows that three moths were found in the jar of wintering larvæ at that time; while these may have emerged two or three days previously, from the number appearing two days later (May 10) it can be assumed that moth emergence was just beginning on May 8.

TABLE VI.—*Emergence of spring-brood moths of the codling moth at Greenwood, Va., in 1912.* (See fig. 5.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 8	3	May 30	34
10	11	June 3	15
14	18	7	5
18	28		
22	20	Total	180
26	46		

Some time was spent in the orchard in an unsuccessful search for eggs and young larvæ, and their absence indicates that moths had at least not been appearing in the field in numbers up to that time. Maximum emergence did not occur until May 26, although moths were appearing in some numbers during all of the period from May 10 to June 3. None emerged in the rearing cages after June 7, although, had more insects been under observation, an occasional adult would probably have appeared later.

FIRST-BROOD MOTHS.

The first collection of larvæ in 1912 was delayed until June 12, though as none of those taken under the bands at the time had pupated, the beginning of first-brood moth emergence was not seriously affected thereby. In all 639 moths appeared in the rearing cages between June 23 and August 28. (See Table VII.)

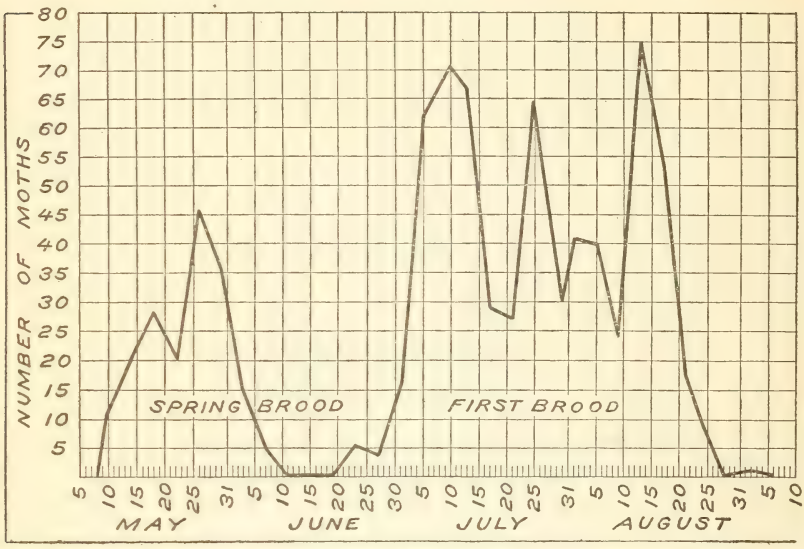

FIG. 5.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Greenwood, Va., in 1912.

TABLE VII.—*Emergence of first-brood moths of the codling moth at Greenwood, Va., in 1912.* (See fig. 5.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 23	6	Aug. 1	41
27	4	5	40
July 1	17	9	24
5	62	13	75
10	71	17	53
13	67	21	18
17	29	24	9
21	27	28	0
25	65		
29	30	Total	639

The seasonal appearance of the two broods of moths is given in figure 5.

Work at Greenwood was discontinued in 1913, the transformations of the codling moth being apparently so nearly the same as at Charlottesville that almost daily observation would be necessary to distinguish any variation at all, and according to the plan of work followed it was impossible to take records oftener than every three or four days.

INVESTIGATIONS AT HAGERSTOWN, MD.

DESCRIPTION OF LOCALITY.

Hagerstown, Md., is situated on a comparatively level portion of the lower Cumberland Valley. The country is more or less rolling, but the relative differences in altitude are not great, the actual elevation above sea level of most of this section being from 500 to 600 feet. There are a few large orchards in the vicinity, but fruit growing in a commercial way has not received much attention until recently. However, Hagerstown is not far from some very important fruit-growing districts on the east, the west, the north, and the south. Band-record experiments were carried on in this section for 1911, 1912, and 1913.

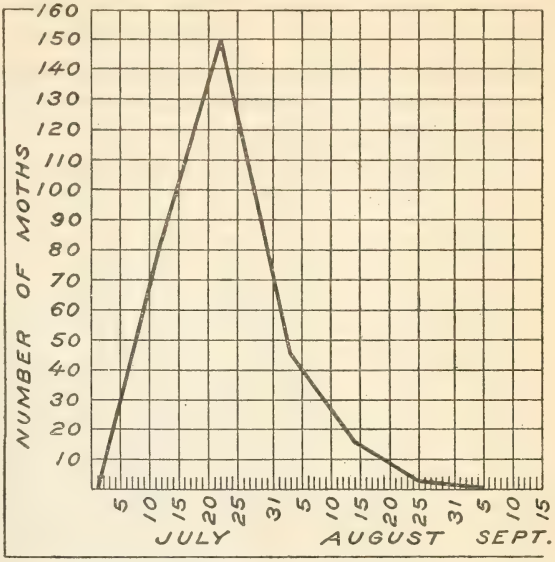

FIG. 6.—Diagram to illustrate emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1911.

INVESTIGATIONS IN 1911.

FIRST-BROOD MOTHS.

The long intervals between observations in 1911 (10 to 12 days) make the records of that year of rather doubtful value, and while they are included for Hagerstown and Pickens, it must not be understood that they are comparable in any but a general way to the data obtained in the two following years' work in these sections.

TABLE VIII.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1911.* (See fig. 6.)

Date of observation.	Number of moths emerging.
July 12	82
22	151
Aug. 3	46
14	16
Aug. 25	3
Total	298

The collection of larvæ from the bands, and the summer-brood moth emergence given in Table VIII, can be better appreciated by reference to figures 6 and 7, and it is doubtful if much could be added by a detailed discussion of the season's work.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

It will be noted that the records for spring-brood moth emergence given in Table IX were obtained at Smithsburg, Md., and therefore do not represent accurately what took place at Hagerstown. The Smithsburg section is 9 miles east of Hagerstown, at the foot of the Blue Ridge Mountains, and at a considerably higher elevation, and

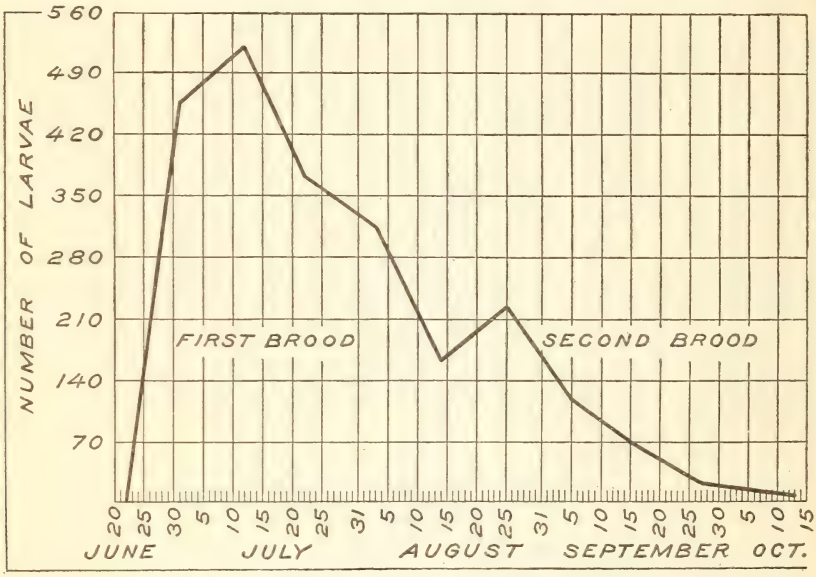

FIG. 7.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1911.

the seasonal conditions at Hagerstown are somewhat in advance of those at Smithsburg. However, no satisfactory record of moth emergence was obtained at Hagerstown in the spring of 1912, and as this was practically the only record of any value secured at Smithsburg, it is included in the report of the work in the former section.

TABLE IX.—*Emergence of spring-brood moths of the codling moth at Smithsburg, Md., in 1912.* (See fig. 8.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 30	2	June 19	10
June 3	9	23	4
7	17		
11	23	Total	85
15	20		

It will be seen from figure 8 that emergence began on May 30, and reached its maximum on June 11, after which time the moths decreased in numbers, ceasing to appear altogether after June 23. It would probably be safe to say that the first-brood larvæ were entering fruit by June 1, or very soon thereafter.

FIRST-BROOD MOTHS.

The emergence records of 148 moths given in Table X were obtained from the material collected in the orchard at Hagerstown and represent fairly well the occurrence of the summer or first brood of moths in the field. The 148 moths accounted for in this table comprise all that transformed during that season of the 1,706 larvæ reared, a fact

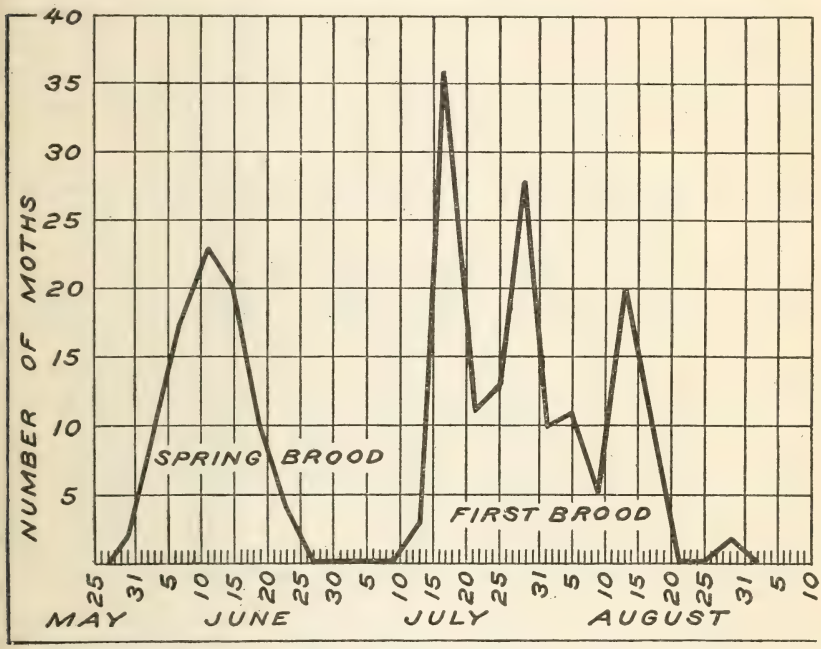

FIG. 8.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Smithsburg, Md., and first-brood moths at Hagerstown, Md., in 1912.

which probably accounts for the relatively small number of second-brood larvæ that appeared under the bands later in the summer (see fig. 9).

TABLE X.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1912.* (See fig. 8.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 13	3	Aug. 13	20
17	36	17	9
21	11	21	.....
25	13	25	.....
29	28	29	2
Aug. 1	10		
5	11	Total	148
9	5		

First-brood moths began to emerge on July 13, and emergence continued throughout the remainder of July and the fore part of August. Two adults appeared as late as August 29, though emergence had practically ceased August 17. The codling moth is very sensitive to weather conditions, its development being especially retarded by cold, and the irregularity in the emergence curve of first-brood moths in figure 8 is due, in part at least, to extreme temperature variations of the season.

Second-brood larvæ probably began entering fruit at Hagerstown in 1912, about July 23 to 27.

BAND COLLECTIONS.

Altogether 1,706 larvæ were taken from the bands at Hagerstown in 1912. (See Table XI.) The trees used were of the York Imperial variety, about 15 years old, smooth bodied and loaded with fruit. Bands were placed in the fore part of June and examinations made every three or four days, beginning June 15.

TABLE XI.—*Number of larvæ of the codling moth taken from the bands and reared at Hagerstown, Md., during the summer of 1912 and the spring of 1913.* (See fig. 9.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number emerged, 1912.	Number overwintering.	Number winter-killed.	Number emerged, 1913.
June 29	11	4	7			
July 1						
5	58		42	16	7	9
9	55	24	28	3	3	
13	144	27	42	75	24	51
17	240	53	15	172	109	63
21	183	44	2	137	137	
25	207	61	10	136	100	36
29	228	75	2	151	112	39
Aug. 1	117	22		95	40	55
5	97	18		79	25	54
9	59	12		47	36	11
13	35	5		30	23	7
17	30	2		28	11	17
21	15	10		5		5
25	60	31		29	19	10
30	30	8		22	2	20
Sept. 2	48	22		26	19	7
6	16	9		7	7	
10	21	7		14	7	7
14	16	4		12	8	4
18	28	8		20	13	7
22	8	2		6	4	2
Total	1,706	448	148	1,110	706	404
Per cent	100	26.26	8.68	65.06	41.38	23.68

From figure 9 it will be seen that the first larvæ appeared under the bands on June 29, the numbers gradually increasing through July. From August 1 to 21 the collections decreased, increasing again slightly after the latter date, and it is probable that second-brood larvæ were beginning to leave the apples about this time. Only 8.68 per cent of the first-brood larvæ transformed to moths, which explains the relatively small second brood of larvæ shown in figure 9.

Comparison of figures 7 and 9 would suggest that, in the relative numbers of the two broods of larvæ appearing under the bands, the seasons of 1911 and 1912 were very similar.

As has already been said, only 8.68 per cent of the 1,706 larvæ taken under the bands at Hagerstown in 1912 transformed to moths that summer. The percentage of 26.26 that died in the rearing cages from handling, cannibalism, disease, immaturity, and other causes compares closely with that observed at other points, and the rearing work was evidently done with as much care and under as favorable conditions as in the localities where a much larger proportion of the first brood transformed; 65.06 per cent wintered, 41.38 per cent were winter-killed, and 23.68 per cent emerged as moths

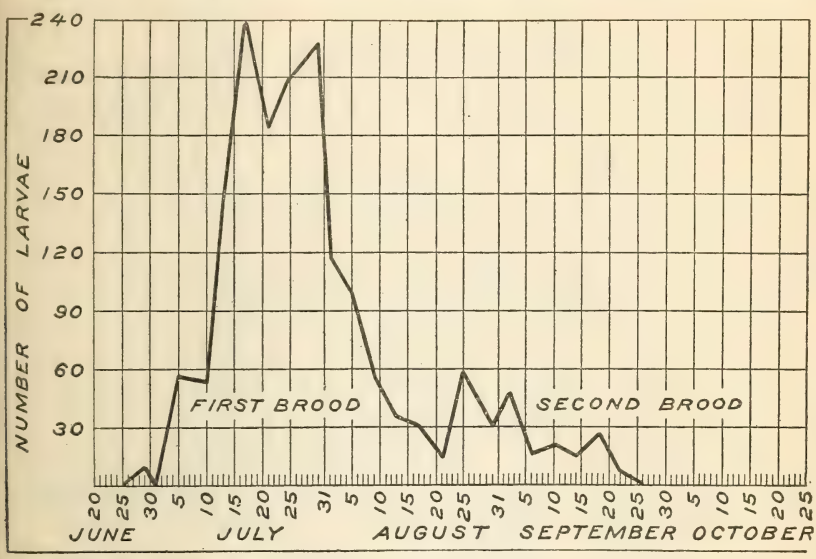

FIG. 9.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1912.

in the spring of 1913. The percentage of winter-killed larvæ at Hagerstown was much larger than in other localities that year.

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in rearing cages at Smithsburg, Md., on May 30 (probably several days later than at Hagerstown). First-brood larvæ were probably entering fruit 10 to 12 days later (soon after June 1, at Hagerstown). First-brood larvæ were leaving apples in the field from June 25 to 29 to August 17 to 21.

First-brood moths began emerging from field-collected material on July 13. Second-brood larvæ probably began feeding soon after July 23, and were leaving the fruit in numbers soon after August 21.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Table XII gives the emergence of moths of the spring brood at Hagerstown in 1913.

TABLE XII.—*Emergence of spring-brood moths of the codling moth at Hagerstown, Md., in 1913.* (See fig. 10.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 15	2	June 5	45
18	6	8	22
21	12	11	25
24	9	27	81
27	38		
30	77	Total	404
June 2	87		

The first moths appeared in the rearing cages on May 15, but maximum emergence did not occur until May 30 to June 2. Careful

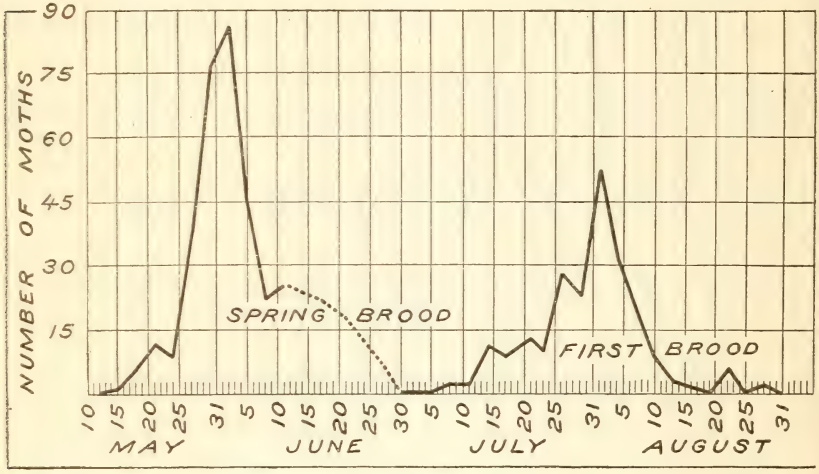

FIG. 10.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Hagerstown, Md., in 1913.

records were taken every three days up to and including June 11, but from June 11 to June 27 observations were discontinued, as indicated by the dotted line in figure 10. However, of 404 moths accounted for in Table XII, all but 81 had emerged by June 11, and the break from then until June 27 does not seriously affect the value of the records. Allowing 10 to 12 days for egg laying and incubation, first-brood larvæ were evidently beginning to feed by May 25 to 27.

FIRST-BROOD MOTHS.

The relation of the two broods of moths emerging at Hagerstown in 1913 is clearly illustrated in figure 10. Adults appeared in the rearing jars with more or less regularity from July 8 to August 10. Emergence ceased altogether on August 28. (See also Table XIII.)

TABLE XIII.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1913.* (See fig. 10.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 8	2	Aug. 7	20
11	2	10	8
14	11	13	3
17	8	16	1
21	13	19	0
23	10	22	6
26	29	25	0
29	23	28	2
Aug. 1	53		
4	31	Total	222

Probably a few second-brood larvæ were entering fruit in the field by July 20 to 25.

BAND COLLECTIONS.

In Table XIV are given the records of the collections and rearings of 2,756 larvæ taken under the bands at Hagerstown in the summer of 1913.

TABLE XIV.—*Number of larvæ of the codling moth taken from bands and reared at Hagerstown, Md., during the summer of 1913.* (See fig. 11.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1913.	Number overwintering.
June 27	3	1	2	.....
30	12	4	8	.....
July 2	38	12	17	9
5	30	6	18	6
8	78	19	24	35
11	86	31	34	21
14	136	38	41	57
17	95	22	24	49
21	181	53	28	100
23	116	22	14	80
26	150	77	7	66
29	108	44	4	60
Aug. 1	105	40	.....	65
4	73	11	1	61
7	109	36	3	70
10	108	27	1	80
13	101	11	.....	90
16	148	49	1	98
19	121	41	.....	80
22	110	28	.....	82
25	26	6	.....	20
28	128	[1] 104	.....	24
31	92	16	.....	76
Sept. 3	203	48	.....	155
6	111	34	.....	77
9	127	61	.....	66
12	42	8	.....	34
15	32	12	.....	20
18	14	4	.....	10
21	18	8	.....	10
25	9	5	.....	4
27	17	1	.....	16
30	9	3	.....	6
Oct. 3	5	.....	.....	5
6	5	1	.....	4
9	6	.....	.....	6
12	2	.....	.....	2
15	1	.....	.....	1
18	1	.....	.....	1
Total	2,756	883	227	1,646
Per cent	100	32.04	8.24	59.72

[1] Eaten by mice.

Larvæ began to appear on June 27, and were taken under the bands in numbers through the remainder of June, all of July, and part of August. It will be noticed that on August 25 (fig. 11) there was a sharp decrease in the number of insects collected. Considering the time first-brood moths began appearing in the rearing cages at Hagerstown, and correlating with what was taking place at Winchester and elsewhere, second-brood larvæ very likely began appear-

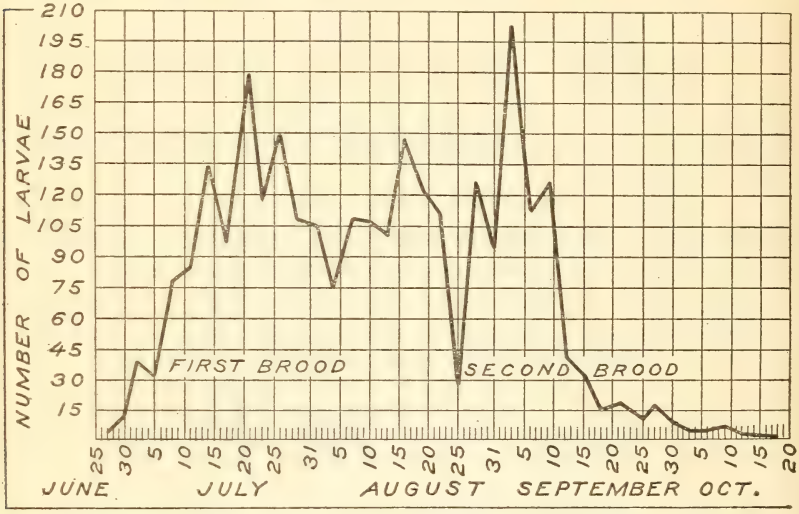

FIG. 11.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1913.

ing under the bands soon after August 25, though an unusual overlapping of the two broods of larvæ is apparent in the collections. Records were discontinued about October 25, though no larvæ appeared under the bands later than October 18.

The 8.24 per cent of transforming larvæ taken under the bands at Hagerstown in 1913 compares closely with the 8.68 per cent that transformed in 1912. The 32.04 per cent of larvæ that died from handling, cannibalism, etc., in 1913 is much higher than has usually been observed, due in part to the fact that one jar of larvæ was devoured by mice, and discarding consideration of this cage the loss is brought down to 29.37 per cent. The 59.72 per cent of wintering larvæ is only slightly less than the 65.06 per cent obtained in 1912.

SUMMARY FOR SEASON OF 1913.

Spring-brood moth emergence began May 15 and closed June 27. Allowing 10 to 12 days from emergence to hatching of first eggs, we might expect that first-brood larvæ began entering the apples May 25 to 27. First-brood larvæ appeared under the bands on June 27. First-brood moths began to emerge in the rearing cages on July 8,

though not in numbers until July 11 to 14. Second-brood larvæ were probably beginning to enter the fruit about July 20 to 25 and were leaving in numbers after August 25.

INVESTIGATIONS AT WINCHESTER, VA.

DESCRIPTION OF LOCALITY.

Winchester, the county seat of Frederick County, Va., is one of the principal shipping points for a large and well-developed apple-producing territory in the northern part of the Shenandoah Valley. The altitude of most of the country immediately surrounding Winchester varies from 650 to 800 feet above sea level; thus the relative variations in elevation are not great and the seasonal conditions are fairly uniform for the whole section. The life-history studies of the codling moth in this section for the seasons of 1912 and 1913 follow.

In Table XV are included the emergence records of 94 moths that issued at Winchester in the spring of 1912.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

TABLE XV.—*Emergence of spring-brood moths of the codling moth at Winchester, Va., in 1912.* (See fig. 12.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 22	2	June 11	8
26	4	15	4
30	19	19	1
June 3	26	23	3
7	26	27	1
		Total	94

The first moth appeared in the laboratory rearing cages between May 18 and 22, though observations indicate that moths emerged several days earlier in the field. On the 24th of May eggs were rather common in the orchard, and two newly hatched larvæ were found just entering apples. Certainly moths were emerging in the field, in 1912, not later than May 15. By May 30 first-brood larvæ were observed entering fruit in the orchard in considerable numbers. The last spring-brood moth emerged June 27.

The fruit was unusually large when attacked by the codling moth in 1912, and it is of some interest to note that curculio cuts and rough spots on the apples were more frequently used by the first-brood larvæ as points of entrance than was the calyx end of the fruit.

The first of the 1912 summer or first-brood moths emerged on July 9. Eggs were laid by moths in confinement on July 13, by moths emerging during the period from July 9 to 13, but since one moth issued

July 9 it is possible oviposition began two or three days earlier in the field. Moths emerged in the rearing cages until August 21. (See Table XVI.)

FIRST-BROOD MOTHS.

TABLE XVI.—*Emergence of first-brood moths of the codling moth at Winchester, Va., in 1912.* (See fig. 12.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 9	1	Aug. 2	25
13	20	6	8
17	25	10	23
20	27	14	18
25	27	18	13
29	33	21	8
		Total	228

The relation of the two broods of moths can be better understood by reference to figure 12, where their seasonal appearance is represented graphically.

BAND COLLECTIONS.

An old unsprayed orchard located about a mile south of Winchester was used for the band-record experiments of 1912. The trees

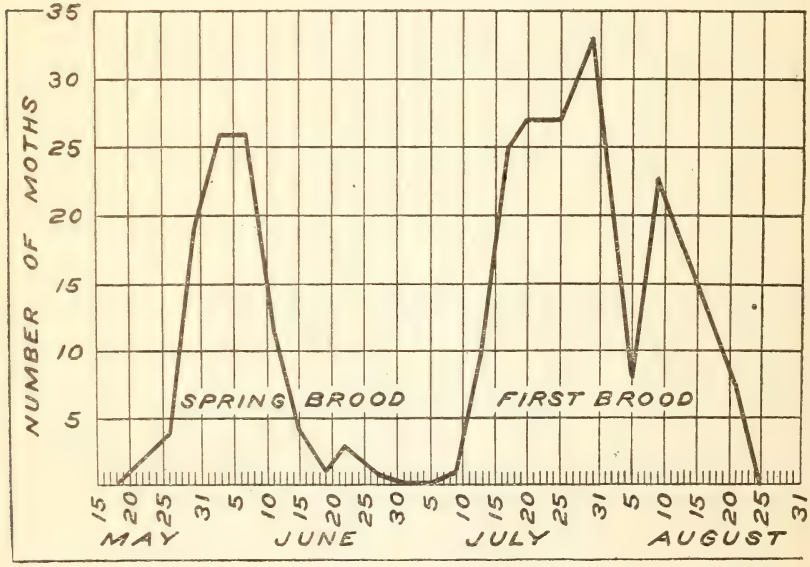

FIG. 12.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Winchester, Va., in 1912.

were of late fall and winter varieties well laden with fruit, and the infestation was very extensive, practically every apple being attacked by one or more codling-moth larvæ at some time during the season.

One larva was taken under the bands on June 19. The number collected increased throughout the remainder of June and the first half of July. By referring to figure 13 it will be noticed that during the fore part of August there occurred a series of very small collections, and about this time evidently most of the first-brood larvæ had left the fruit, while those of the second brood were still feeding. On July 15 newly hatched larvæ were observed entering fruit in the field in sufficient numbers to exclude the probability of their belonging to the first brood, especially since the last of the spring-brood moths appeared on June 27. The second-brood larvæ did not hatch in the laboratory until July 19, but this was probably three or four days behind field conditions. Allowing for a normal feeding

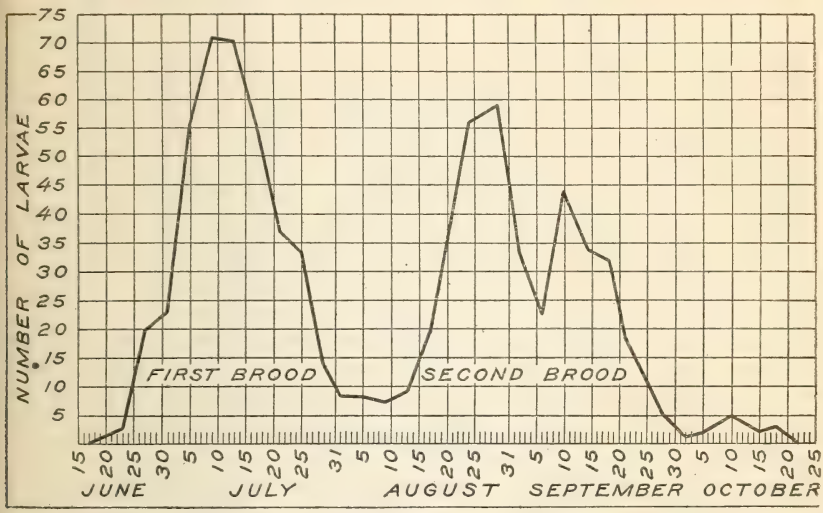

Fig. 13.—Diagram to illustrate band collections of larvæ of the codling moth at Winchester, Va., in 1912.

period, some of the second-brood larvæ should have been leaving the apples about August 9 to 13. The collections increased through the latter part of August and the first half of September. No larvæ appeared under the bands after October 18.

During the season of 1912 at Winchester 798 larvæ were taken from the bands and reared. Of these 27.19 per cent were killed in handling or were devoured by their fellows after being placed in the rearing cages; 28.57 per cent emerged as moths of the first brood; 1.38 per cent were parasitized; 42.86 per cent of the larvæ collected wintered, and 15.04 per cent were winter killed; 27.44 per cent passed the winter successfully and emerged the following season, while 0.38 per cent represents the proportion of parasites that issued in the spring of 1913. (See Table XVII.)

TABLE XVII.—*Number of larvæ of the codling moth taken from the bands and reared at Winchester, Va., during the summer of 1912 and the spring of 1913.* (See fig. 13.)

Date of collection, 1912.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Emerged, 1912.		Number of larvæ overwintering.	Number of larvæ winter-killed.	Emerged, 1913.	
			Moths.	Parasites.			Moths.	Parasites.
June 19	1		1					
23	3		3					
27	20	5	14		1	1		
July 1	23		23					
5	56	16	36	3	1	1		
9	71	24	42	4	1		1	
13	70	31	37	1	1		1	
17	56	16	31	3	6	2	4	
21	37	11	19		7	1	6	
25	33	17	11		5	1	4	
29	14	2	6		6		6	
Aug. 1	8	1	4		3		3	
5	8		1		7		7	
9	7	1			6	2	4	
13	9	1			8		8	
17	19	5			14	4	10	
21	37	7			30	8	21	1
24	56	4			52	19	33	
29	59	3			56	29	27	
Sept. 2	32	14			18	6	10	2
6	22	6			16	7	9	
10	44	17			27	15	12	
14	34	3			31	14	17	
18	32	6			26	10	16	
21	18	10			8		8	
25	11	6			5		5	
28	5	2			3		3	
Oct. 2	1				1		1	
5	2	1			1		1	
10	5	4			1		1	
15	2	1			1		1	
18	3	3						
Total	798	217	228	11	342	120	219	3
Per cent	100	27.19	28.57	1.38	42.86	15.04	27.44	0.38

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in the laboratory May 18 to 22, and probably two or three days earlier in the field. First-brood larvæ began entering the fruit in the field May 24. First-brood larvæ began leaving the apples June 19. First-brood moths began emerging July 9; second-brood larvæ were observed entering fruit in the field on July 15, and a few had finished feeding by August 9 to 13.

INVESTIGATIONS IN 1913.

SPRING-BROOD AND FIRST-BROOD MOTHS.

The seasonal conditions of the spring of 1913 were considerably in advance of those of 1912, and the appearance of the spring-brood moths was correspondingly earlier. Moths appeared in numbers on May 6 and maximum emergence occurred three days later.

TABLE XVIII.—*Emergence of spring-brood moths of the codling moth at Winchester, Va., in 1913.* (See fig. 14.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 6	18	June 2	14
9	38	5	10
12	6	8	6
15	16	11	3
18	30	14	7
21	29	17	3
24	8	20	1
27	16		
30	14	Total	219

Moths continued to issue in the rearing cages until June 20. The irregularity of the emergence curve in figure 14 is due in most cases

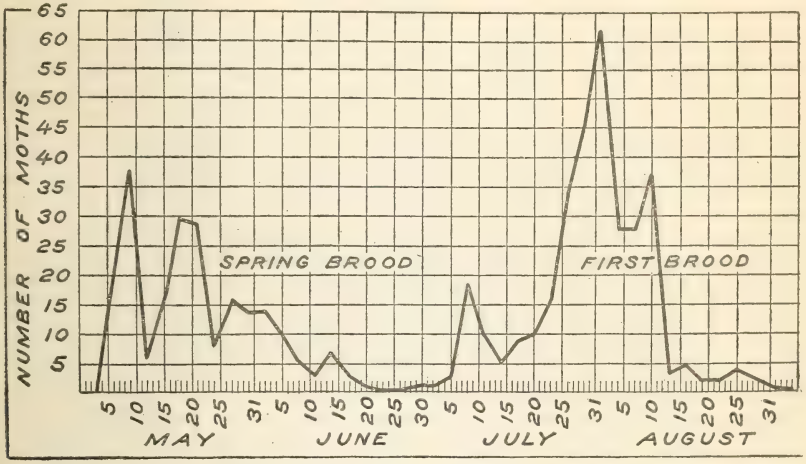

FIG. 14.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Winchester, Va., in 1913.

to fluctuations in temperature. The first moth emergence in confinement occurred 16 days earlier in 1913 than in 1912, but since adults were probably appearing in the field in 1912 not later than May 15, we may assume that spring-brood emergence began in the field only 10 to 12 days earlier in 1913.

The seasonal appearance of the two broods of moths can perhaps be best appreciated by referring to figure 14. The emergence of 326 moths of the first brood are given in Table XIX. The first adults of this brood appeared in the laboratory in 1913 on June 30, nine days earlier than in 1912. However, not until July 5 to 8 did adults appear in any numbers, and in reality the difference in the time of appearance of summer, or first-brood, moths in the two seasons is

very slight. Maximum emergence was not attained until one month later, or about August 1. The last of the first-brood moths emerged in the rearing cages on September 1.

TABLE XIX.—*Emergence of first-brood moths of the codling moth at Winchester, Va., in 1913.* (See fig. 14.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 30	1	Aug. 4	28
July 2	1	7	28
5	3	10	37
8	19	13	3
11	10	16	5
14	5	19	2
17	9	22	2
20	10	25	4
23	16	29	2
26	33	Sept. 1	1
29	45		
Aug. 1	62	Total	326

BAND COLLECTIONS.

In 1913 bands were placed on 12 old apple trees in an orchard located about 2 miles south of Winchester. The rough bark was

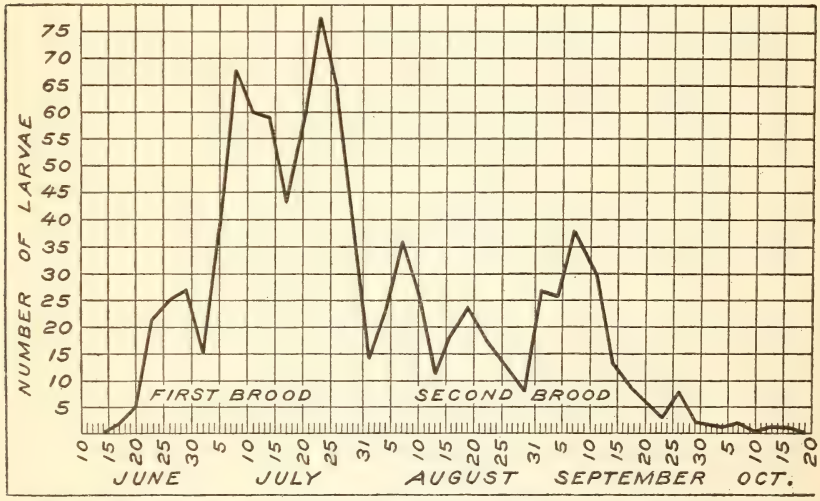

FIG. 15.—Diagram to illustrate band collections of larvæ of the codling moth at Winchester, Va., in 1913.

scraped down and other hiding places of the insect destroyed, and on the whole probably most of the larvæ that left the fruit during the season found their way under the bands. The record of collections is given in Table XX.

TABLE XX.—*Record of codling-moth larvæ taken from the bands and reared at Winchester, Va., in 1913.* (See fig. 15.)

Date of collection.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Emerged, 1913.		Number overwintering.
			Moths.	Parasites.	
June 17	2		2		
20	5	3	2		
23	22	4	14	4	
26	25	9	16		
29	27	5	15	7	
July 2	15	6	9		
5	38	23	15		
8	68	14	40	13	1
11	60	8	47		5
14	59	19	31	2	7
17	43	8	24	5	6
20	57	6	31	8	12
23	84	9	38	11	26
26	63	3	22	12	26
29	38	14	8	3	13
Aug. 1	14	7	3		4
4	23	6	3		14
7	36	11	3		22
10	26	9	2		15
13	11	6	1		4
16	19	9			10
19	24	9			15
22	18	9			9
25	14	5			9
29	8	2			6
Sept. 1	27	16			11
4	26	7			19
7	38	7			31
11	30				30
14	13				13
17	9				9
20	6				6
23	3				3
26	8				8
29	5				5
Oct. 1	2				2
4	1				1
7	2				2
10					
13	1				1
16	1				1
Total	971	234	326	65	346
Per cent	100	24.10	33.57	6.70	35.63

Careful examination of the bands was made, beginning about June 1, but no larvæ were taken until June 17, only two days earlier than in 1912, in spite of the fact that the first of the spring-brood moths were probably 10 to 15 days earlier than in the former season. From June 17 the collections increased until about August 1, when the numbers of insects collected decreased slightly, the proportion of those wintering increasing, and probably by August 7 to 10 most of the larvæ taken were of the second brood. The fact that the second brood did not equal the first in numbers and were somewhat irregular in their appearance under the bands is explained by the short fruit crop of the year.

Altogether 971 larvæ were collected and reared. Of this number 24.10 per cent were killed by handling, cannibalism, etc., the loss from this source being about the same as the 27.19 per cent that died from similar causes in 1912; 33.57 per cent were transformed to first-

brood moths and 6.70 per cent were parasitized. The light fruit crop already noted reduced the number of wintering larvæ to 35.63 per cent.

SUMMARY FOR SEASON OF 1913.

Spring-brood moths began to emerge May 6, and a few first-brood larvæ were probably entering the fruit by May 16. First-brood larvæ began to appear under the bands in the orchard June 17, and from these larvæ a few first-brood moths emerged in the laboratory on June 30. Second-brood larvæ were probably entering fruit in numbers by July 15; they began leaving fruit about August 13.

INVESTIGATIONS AT FISHERSVILLE, VA.

DESCRIPTION OF LOCALITY.

Fishersville is the shipping point for a part of the Shenandoah Valley, in which commercial fruit growing has for years been of considerable importance. While in approximately the same latitude as Charlottesville, the seasonal conditions of this section are decidedly different chiefly on account of the much higher altitude; in fact, there is a much greater similarity of conditions between Fishersville and Winchester, both of which are in the Shenandoah Valley, than between Fishersville and Charlottesville, between which two points the Blue Ridge Mountains intervene. Differences in humidity and other climatic conditions occur between these two regions that may effect the development of the codling moth and that may not be entirely accounted for by differences in altitude. The band-record experiments were carried on in locations 1,400 to 1,500 feet above sea level, which is probably about the average elevation of orchards in this section.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

In a limited way the emergence dates of 119 moths given in Table XXI probably represent fairly well the occurrence of the spring brood at Fishersville in 1912. The rearing material was collected from the bands in the fall of 1911.

TABLE XXI.—*Emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1912.* (See fig. 16.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 18	5	June 15	1
22	13	19	
26	14	23	
30	42	27	1
June 3	27		
7	5	Total	119
11	11		

Emergence began on May 18 and reached its highest numbers on May 30, 12 days later. However, since first-brood larvæ appeared under the bands on June 11, it is probable that moths emerged in the field several days prior to May 18. The moths continued to emerge through the remainder of May and in lessening number through the most of June, ceasing to appear altogether after June 27.

The records of the appearance of 273 moths of the first brood that issued from band-collected material at Fishersville in the summer of 1912 are given in Table XXII.

FIRST-BROOD MOTHS.

TABLE XXII.—*Emergence of first-brood moths of the codling moth at Fishersville, Va., in 1912.* (See fig. 16.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 2	5	Aug. 1	15
5	7	5	13
9	35	9	16
13	30	13	1
17	55	17	3
21	35	21	1
25	31		
29	26	Total	273

The work at Fishersville in 1912 was carried on under very ideal conditions, and July 2, the time when the first-brood moths began emerging in the rearing cages, represents field conditions as nearly as is possible with band-collected rearing material. The time of first appearance for the first-brood moths was seven days in advance of Winchester, while between the first emergence of spring-brood moths there was a four-day difference in the two sections.

Moths appeared in numbers through July and the first half of August, attaining their maximum on July 17. The last moth appeared in the rearing cages on August 21. The relative time of appearance of the two broods of moths at Fishersville in 1912 is shown in figure 16.

BAND COLLECTIONS.

About 12 smooth-bodied young York Imperial and Ben Davis apple trees were banded at Fishersville in 1912. On the whole the records given in Table XXIII and figure 17 represent fairly well the time the two broods of larvæ were leaving the fruit that season. Three larvæ were taken under the bands on July 11 and the number increased in the succeeding collections until about July 1, when the number gradually decreased until the fore part of August. By August 1 a large part of the first brood had left the fruit, as is evidenced in the band-record curve of figure 17.

Since first-brood moths emerged in the rearing cages on July 2, larvæ hatching from eggs laid by these moths might reasonably be expected to begin feeding by July 12 to 15. After August 9 the

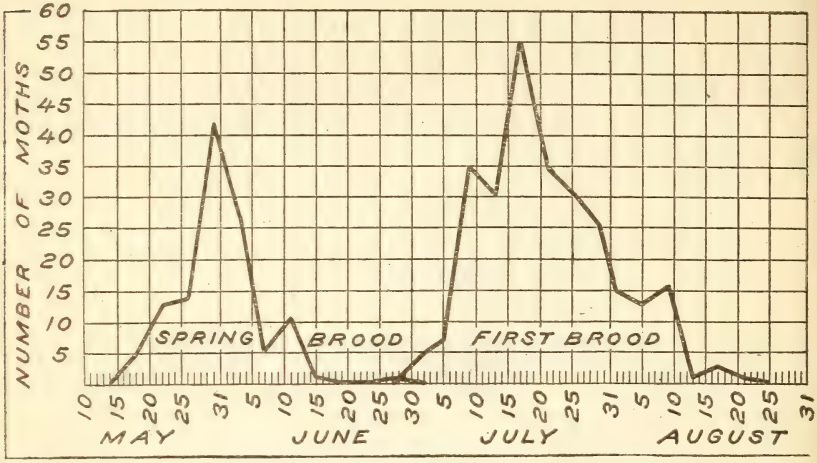

FIG. 16.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Fishersville, Va., in 1912.

collections increased to the middle of September. Second-brood larvæ continued to appear under the bands until November 1, when the fruit was picked and the records discontinued.

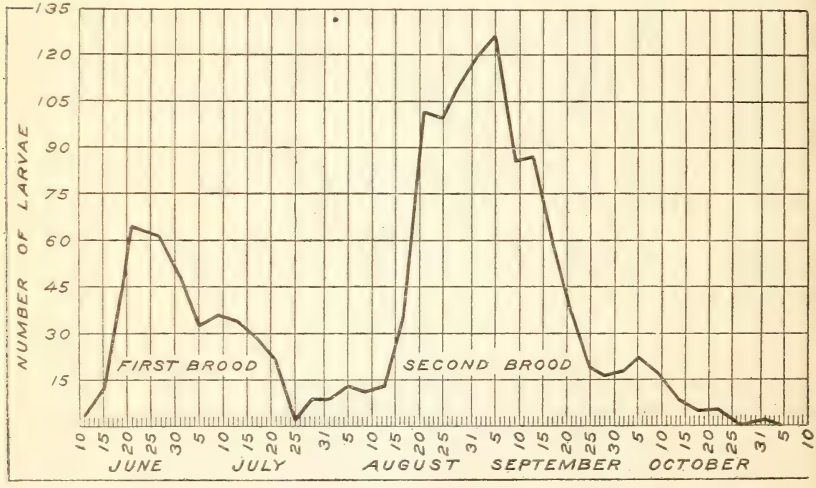

FIG. 17.—Diagram to illustrate band collections of larvæ of the codling moth at Fishersville, Va., in 1912.

In Table XXIII are recorded the numbers of larvæ taken in the orchard at different dates through the season. Altogether 1,418 larvæ were collected and reared, of which 12.90 per cent were killed

by handling or devoured by their fellows in the rearing cages; 19.96 per cent emerged as adults during the summer of 1912; 67.14 per cent wintered and 24.19 per cent were winter killed; and 42.95 per cent emerged as moths in the spring of 1913.

TABLE XXIII.—*Number of larvæ of the codling moth taken from the bands and reared at Fishersville, Va., during the summer of 1912 and the spring of 1913.* (See fig. 17.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from cannibalism, etc.	Number of moths emerging, 1912.	Number of larvæ overwintering.	Number of larvæ winter killed.	Number of moths emerging, 1913.
June 11	3	1	2			
15	12	3	9			
19	43	13	30			
21	64	41	23			
27	61	11	50			
July 1	48	14	34			
5	32	5	27			
9	35		28	7		7
13	34	3	28	3		3
17	29		23	6		6
21	22	2	16	4		4
25	1		1			
29	9	1	2	6		6
Aug. 1	9		5	4	2	2
5	14		4	10		10
9	11	1	1	9		9
13	13	2		11	9	2
17	36			36	12	24
21	101	2		99	46	53
25	100	17		83	43	40
28	109	14		95	44	51
Sept. 1	120	23		97	34	63
5	127	15		112	39	73
9	86	6		80	28	52
13	88	2		86	37	49
17	61	2		59	32	27
21	37			37	11	26
25	19			19		19
28	16			16	3	13
Oct. 2	18			18		18
5	22	3		19		19
9	17	1		16	3	13
14	8			8		8
18	5			5		5
22	6	1		5		5
27						
Nov. 1	2			2		2
Total	1,418	183	283	952	343	609
Per cent	100	12.90	19.96	67.14	24.19	42.95

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in the laboratory May 18 and probably several days earlier in the field. Ten to 12 days later first-brood larvæ were probably beginning to enter fruit. First-brood larvæ began leaving the fruit June 11. First-brood moths emerged July 2 to August 21, and second-brood larvæ probably were entering fruit by July 12. Soon after August 5 to 9 the number of larvæ appearing under the bands increased, and most of the larvæ taken after this date may be considered to be of the second brood.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Figure 18 represents the occurrence of 608 moths of the spring brood that appeared in the rearing cages at Fishersville in 1913. Moths emerged first on May 3, but maximum emergence was delayed until May 30, the emergence curve in figure 18 for Fishersville being very different in this respect from the spring-brood curve at Winchester, as it appears in figure 14. Adults continued to emerge until June 27. (See also Table XXIV.)

TABLE XXIV.—*Emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1913.* (See fig. 18.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 3	6	June 5	44
6	1	8	10
9	3	11	9
12	9	14	22
15	11	17	10
18	53	20	7
21	28	24	3
24	94	27	2
27	91		
30	124	Total	608
June 2	81		

First-brood larvæ were probably entering the fruit in the field by May 10 to 13, from eggs laid by moths emerging May 1 to 3.

On account of the light crop of fruit in 1913 the records at Fishersville for the remainder of the season are of little value and are not included in this report

INVESTIGATIONS AT FRENCH CREEK, W. VA.

DESCRIPTION OF LOCALITY.

French Creek is located near the lower border of the Transition Life Zone in a hilly region not far from the center of West Virginia. Commercial apple growing is just beginning to attract attention, and several orchards of considerable size are being planted in that general locality. Bearing orchards of from 5 to 25 acres are not uncommon. The orchards from which banding records were obtained are located at an approximate elevation of 1,600 feet above the level of the sea.

INVESTIGATIONS IN 1911.

On June 19, 1911, 15 suitable apple trees in an orchard that had never been sprayed were banded, but it was found that the bands were placed too late in the season to obtain a complete record of the time of emergence from the fruit of the first-brood larvæ. The bands

furnished a supply of wintering larvæ to be used for emergence records of the spring brood of moths in 1912.

Predaceous and parasitic enemies of the codling moth were possibly more abundant here than in any other orchard in which banding records were made during the investigation. The second-brood larvæ were very extensively parasitized by hairworms (*Mermis* sp.). Of the larvæ of this brood, 71 out of 159, or nearly 50 per cent, died from this cause.

The first-brood moths began to appear in the jars on July 5, when five were found. The maximum was reached on July 8, and from that time the numbers gradually diminished until September 13, when the last two of the season appeared.

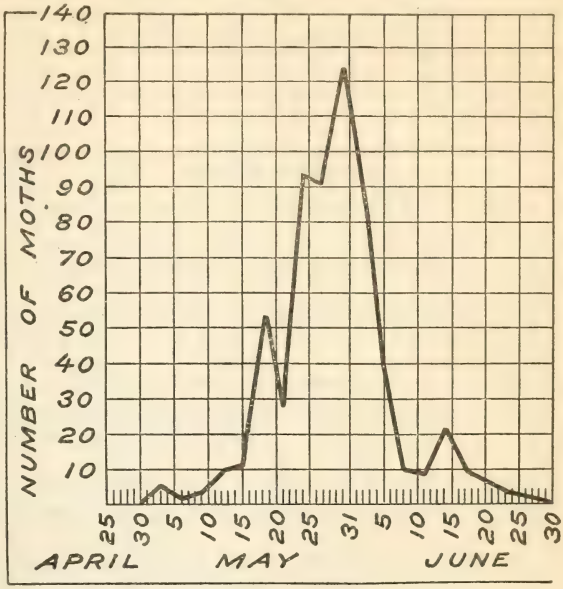

FIG. 18.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1913.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

On account of the high mortality, due to parasites and other causes, only about 50 wintering larvæ were alive to pupate in the spring. Pupation took place from April 22 to 28.

TABLE XXV.—*Emergence of spring-brood moths of the codling moth at French Creek, W. Va., in 1912.* (See fig. 19.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 13	1	May 25	16
14	2	29	4
16	3	June 1	2
21	8	Total	36

Table XXV shows that the first moths of this brood issued on May 13, the last on June 1, and the greatest number on May 25. The last petals were dropping from apple on May 10, so that the first moth

appeared 3 days after the blossoms were off and the maximum moth emergence occurred from 10 to 12 days later.

FIRST-BROOD MOTHS.

As indicated in Table XXVI, first-brood moths made their appearance in the jars on July 20, when seven were found. The number increased up to July 28, and from that date until August 17 maximum

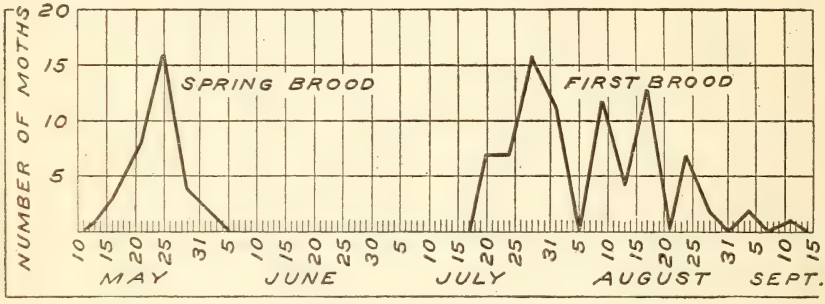

FIG. 19.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at French Creek, W. Va., in 1912.

numbers appeared. After the latter date the numbers decreased until September 11, when the last one issued.

TABLE XXVI.—*Emergence of first-brood moths of the codling moth at French Creek, W. Va., in 1912.* (See fig. 19.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 20	7	Aug. 24	7
24	7	28	2
28	16	31	.....
Aug. 1	11	Sept. 4	2
5	.....	7	.....
9	12	11	1
13	4		
17	13	Total	82
21	.....		

BAND COLLECTIONS.

About the middle of June, 12 apple trees were banded in an old orchard that had never been sprayed. The bands were examined twice each week. This year the larvæ were later by at least a week in beginning to leave the fruit than in 1911. The extent and dates of the collections are set forth in Table XXVII and figure 20.

TABLE XXVII.—*Record of codling-moth larvæ collected under bands at French Creek, W. Va., during the season of 1912.* (See fig. 20.)

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
June 24..	2	Aug. 5...	7	Sept. 18...	20
26..	0	9...	8	21...	22
29..	2	13...	10	25...	24
July 3...	5	17...	12	28...	13
6...	7	21...	12	Oct. 2....	8
10...	19	24...	6	5....	14
13...	12	28...	7	9....	8
17...	16	31...	5	12....	5
20...	10	Sept. 4....	17	16....	2
24...	16	7....	11		
28...	13	11...	10	Total.	339
July 31....	5	14...	11		

The first two larvæ were found on June 24. After June 26 the numbers increased with each collection until July 10. From that

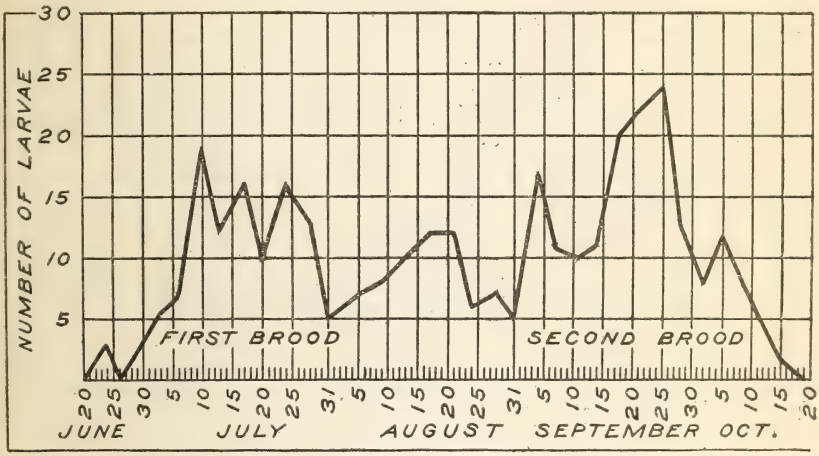

FIG. 20.—Diagram to illustrate band collections of codling moth larvæ at French Creek, W. Va., in 1912.

date until July 28 the size of the collections remained fairly constant. Collections were smaller from July 31 to August 13, after which time they increased until September 25, decreasing thereafter until October 16, when the last two were taken.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

The details of the spring-brood moth emergence are set forth in Table XXVIII and are also shown graphically in figure 21.

TABLE XXVIII.—*Emergence of spring-brood moths of the codling moth at French Creek, W. Va., in 1913.* (See fig. 21.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 6	1	June 7	11
10	11	10	0
13	4	14	8
17	18	17	6
20	25	21	5
24	4	24	2
27	11		
31	9	Total	134
June 3	19		

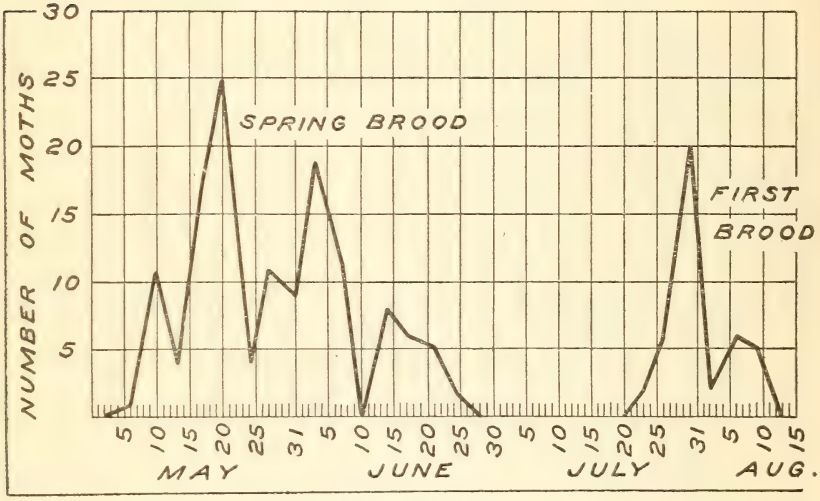

FIG. 21.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at French Creek, W. Va., in 1913.

The first moth was found in the jars on May 6, the maximum numbers from May 17 to June 7, and the last on June 24. A freeze occurring on the night of April 20 caught the apple trees just coming into full bloom, practically destroying the entire crop of blossoms. The first moth appeared 16 days after the date of the freeze, and the maximum emergence was a little more than four weeks after the freeze.

FIRST-BROOD MOTHS.

Owing to the light crop of apples only a few larvæ were obtained, and the number of first-brood moths emerging was insignificant. Table XXIX shows the number that were obtained.

TABLE XXIX.—*Emergence of first-brood moths of the codling moth at French Creek, W. Va., in 1913.* (See fig. 21.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 23	2	Aug. 6	6
26	6	9	5
30	20		
Aug. 2	2	Total	41

It will be seen from this table that only 41 first-brood moths were obtained. Of these the first emerged on July 23, the maximum number on July 30, and the last on August 9.

BAND COLLECTIONS.

A period of cold, occurring April 20 and 21, when the temperature dropped to 20° F., followed by another drop to 25° F. on the night of May 10, destroyed practically all the apple crop in the locality. One old orchard containing a few bearing trees that were not sprayed was found and eight of the trees were banded on July 1. Table XXX shows the number of larvæ collected under these bands.

TABLE XXX.—*Record of codling-moth larvæ collected under bands at French Creek, W. Va., in 1913.*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
July 5	6	Aug. 6	6	Sept. 6	4
9	17	9	4	10	1
12	19	13	7	13	2
16	18	15	6	17	2
19	5	20	7	20	0
23	8	23	6	24	1
26	10	27	4		
30	3	30	4	Total	143
Aug. 2	1	Sept. 3	2		

This table shows that the first larvæ were found under the bands on July 5, the greatest number, which was 19, on July 12, and the last on September 24. The second-brood larvæ were few in number, the collections being nearly uniform from August 6 to 23, after which time they decreased until the last was found.

INVESTIGATIONS AT PICKENS, W. VA.

DESCRIPTION OF LOCALITY.

The orchard at Pickens in which banding records were obtained in 1911 and 1912 is located in a mountainous region at an elevation of 3,500 feet above the level of the sea. The native flora and fauna of the immediate locality indicate the junction of the Transition and

Canadian Life Zones. Fruit growing is not extensively engaged in, although a considerable quantity of apples is produced and disposed of in lumber camps and other local markets.

The codling moth was less abundant here than in other localities where banding records were made. This was probably due to the higher elevation and the consequently shorter breeding season. Data were collected only in 1911 and 1912, the apple crop being an entire failure in 1913.

INVESTIGATIONS IN 1911.

On the 22d of June, 18 apple trees were banded in the orchard of Mr. Lewis Wunchner, 4 miles southeast of the village of Pickens. The orchard had never been sprayed and most of the trees banded were bearing heavy crops of fruit.

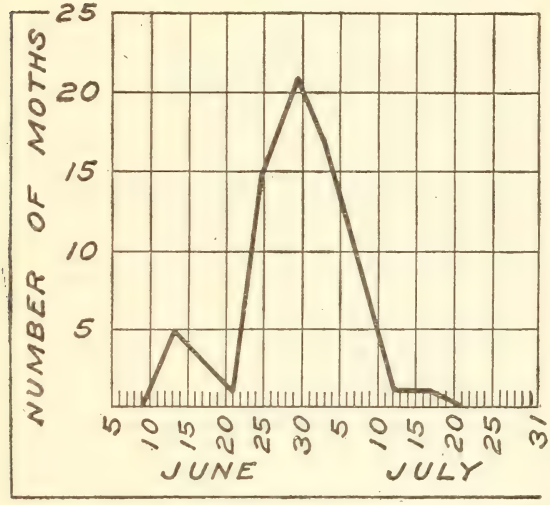

FIG. 22.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Pickens, W. Va., in 1912.

BAND COLLECTIONS.

The first larvæ were found under the bands on July 7, on which date 27 were collected. The maximum number were found on July 19. The last were found on September 29, at which time the fruit was gathered from the trees by the owner of the orchard. The number of larvæ found had dropped from 75, on September 11, to 17 on September 29, and it is probable that only a few more individuals would have gone under the bands had the fruit remained on the trees longer. The details of the band collections are shown more fully in Table XXXI.

TABLE XXXI.—*Record of codling-moth larvæ and pupæ collected under bands at Pickens, W. Va., in 1911.*

Date of collection.	Number of larvæ.	Number of pupæ.	Total.	Number of larvæ wintering.	Per cent of larvæ wintering.
July 7	27	.....	27	.....	.....
19	82	36	118	4	3.5
29	36	7	43	6	13.9
Aug. 8	23	6	29	15	51.7
18	58	3	61	47	77
28	28	1	29	23	79.3
Sept. 11	75	.....	75	75	100
29	17	.....	17	17	100
Total number collected			399		

FIRST-BROOD MOTHS.

Table XXXII shows that of the 59 first-brood moths reared the first were found in the breeding jars on July 29, the maximum numbers from August 8 to 28, and the last on September 11.

TABLE XXXII.—*Emergence of first-brood moths of the codling moth at Pickens, W. Va., during the season of 1911.*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 29	14	Aug. 28	5
Aug. 8	20	Sept. 11	1
18	19	Total	59

INVESTIGATIONS IN 1912.

In 1912 the same orchard was used for the banding records as in 1911, although in most cases different trees were banded. Twelve trees were used.

SPRING-BROOD MOTHS.

Table XXXIII indicates the numbers and dates of emergence of this brood of moths at Pickens.

TABLE XXXIII.—*Emergence of spring-brood codling moths at Pickens, W. Va., during the season of 1912.* (See fig. 22.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 13	5	July 3	17
17	3	8	8
21	1	12	1
25	15	17	1
29	21	Total	72

Moths from the larvæ that had wintered in the rearing jars did not begin to emerge until nearly the middle of June, as is shown in the table. The first were found in the jars on June 13, the greatest numbers from June 25 to July 3, and the last on July 17.

BAND COLLECTIONS.

Larvæ were exceedingly scarce, as is shown in Table XXXIV, only 47 being taken under the bands during the entire season. The first was found on July 24 and the last on October 5. The numbers are so few that no distinct line can be drawn between the first and second broods.

TABLE XXXIV.—*Record of codling-moth larvæ collected under bands at Pickens, W. Va., during the season of 1912.*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
July 24..	1	Aug. 24..	2	Sept. 18..	7
30..	2	28..	1	21..	1
Aug. 5..		31..	4	25..	5
10..	2	Sept. 4..	3	28..	5
14..	1	7	2	Oct. 5..	2
17..	1	11..	5		
21..	2	14..	1	Total..	47

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Of the 47 larvæ collected in 1912, 28 wintered and transformed to moths in 1913. Table XXXV shows the time of emergence.

TABLE XXXV.—*Emergence of spring-brood codling moths at Pickens, W. Va., during the season of 1913.*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 21	0	July 1	8
24	8	5	4
28	8	8	0
		Total	28

The jars in which the larvæ had wintered were examined twice a week and on June 24 eight moths, which were the first of the season, were found. The same number were found on June 28, and also on July 1. The last were found on July 5.

RÉSUMÉ OF REARING EXPERIMENTS IN MARYLAND, VIRGINIA, AND WEST VIRGINIA.

Tables XXXVI and XXXVII summarize the rearing experiments of 1912 and 1913 in the different localities.

TABLE XXXVI.—*Résumé of rearing experiments on the codling moth at five points in Virginia, West Virginia, and Maryland in 1912.*

Observation.	Hagerstown, Md.		Winchester, Va.		Fishersville, Va.		Charlottesville, Va.		French Creek, W. Va.		Total.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Larvæ collected	1,706	100.00	798	100.00	1,418	100.00	905	100.00	339	100.00	5,166	100.00
Larvæ dying from handling, cannibalism, etc	448	26.26	217	27.19	183	12.90	164	18.12	80	23.60	1,092	21.12
Moths reared same season	148	8.68	228	28.57	283	19.96	247	27.29	82	24.19	988	19.12
Moths reared following season	404	23.68	219	27.44	609	42.95	355	39.23	134	39.53	1,721	33.31
Wintering larvæ	1,110	65.06	342	42.86	952	67.14	494	54.59	172	50.74	3,070	59.42
Winter-killed larvæ	706	41.38	120	15.04	343	24.19	139	15.36	38	11.21	1,346	26.06
Parasitized larvæ	.....	.....	14	1.76	.....	.....	.....	.....	5	1.47	19	.36

TABLE XXXVII.—*Résumé of rearing experiments on the codling moth at four points in Virginia, West Virginia, and Maryland in 1913.*

Observation.	Hagerstown, Md.		Winchester, Va.		Charlottesville, Va.		French Creek, W. Va.		Total.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Larvæ collected	2,756	100.00	971	100.00	542	100.00	143	100.00	4,412	100.00
Larvæ dying from handling, cannibalism, etc	883	32.04	234	24.10	223	41.14	48	33.58	1,388	31.46
Moths emerging same season	227	8.24	326	33.57	270	49.82	41	28.67	864	19.58
Wintering larvæ	1,646	59.72	346	35.63	49	9.04	51	35.66	2,092	47.38
Parasitized larvæ	------	------	65	6.70	------	------	3	2.09	68	1.55

It will be noted that the proportion of larvæ dying in the rearing cages, due to handling, cannibalism, disease, etc., varied from 12.90 per cent to 41.14 per cent. The latter figure, however, is unduly high, the average loss from this source being 21.12 per cent in 1912 and 31.46 per cent in 1913. The proportion of larvæ transforming the same season as that in which they were collected varied from 8.24 per cent at Hagerstown to 49.82 per cent at Charlottesville, with an average of 19.12 per cent in 1912 and 19.58 per cent in 1913. For 1912 from 42.86 per cent to 67.14 per cent of all larvæ collected spun up and wintered, the average for all points being 59.42 per cent. The proportion of wintering larvæ in 1913 was abnormally small on account of the light fruit crop of that year. Loss from winter killing amounted to from 11.21 per cent to 41.38 per cent, the average for all points being 26.06 per cent. Observations on parasitism were made only at Winchester and French Creek, the highest recorded being 6.70 per cent at Winchester in 1913. It must be remembered, however, that the foregoing facts are taken from observations of insects kept in confinement, and only in a limited way indicate what occurs under normal out-of-door conditions.

Table XXXVIII gives the numbers of codling-moth larvæ collected and reared in the course of the work in the different localities.

TABLE XXXVIII.—*Number of codling-moth larvæ collected and reared in the different localities in Virginia, Maryland, and West Virginia during 1911, 1912, and 1913.*

Locality.	Year.	Number of larvæ collected and reared.	Locality.	Year.	Number of larvæ collected and reared.
Charlottesville, Va	1911	1,218	Hagerstown, Md	1911	1,761
	1912	905		1912	1,706
	1913	542		1913	2,756
Greenwood, Va	1911	1,979	French Creek, W. Va	1911	633
	1912	1,862		1912	339
Fishersville, Va	1911	910		1913	143
	1912	1,418	Pickens, W. Va	1911	399
Winchester, Va	1911	2,079		1912	47
	1912	798			
	1913	971	Total	------	20,466

NUMBER OF FIRST-BROOD LARVÆ TRANSFORMING FIRST SEASON.

Table XXXIX shows the numbers of transforming and wintering band-collected larvæ of the first brood for several localities. These data are tabulated for their value in determining the relative size of the second brood of larvæ.

TABLE XXXIX.—*Number of first-brood larvæ of the codling moth transforming to moths the first season.*

Locality.	Year	Number of first-brood larvæ living to transform.	Number of first-brood larvæ transforming first season.	Per cent transforming first season.	Number of first-brood larvæ wintering.
Charlottesville, Va	1912	259	247	95.37	12
Do	1913	278	269	96.76	9
Hagerstown, Md	1912	1,122	147	13.19	974
Do	1913	1,356	227	16.74	1,129
Fishersville, Va	1912	308	278	90.26	30
Winchester, Va	1912	266	228	85.71	38
Do	1913	476	325	68.28	151
Keyser, W. Va	1911	226	221	97.78	5
French Creek, W. Va	1911	202	201	99.50	1
Do	1912	93	81	87.10	12
Pickens, W. Va	1911	154	59	38.31	95
Total		4,740	2,284	48.19	2,456

Since an indeterminate number of larvæ always die in the jars on account of artificial conditions, only those that lived to emerge as moths are considered in this table. It will be seen that there is a great variation in the percentage of the larvæ wintering in the different localities, and that in no case did all the first-brood larvæ transform to moths the first season. At Charlottesville, Fishersville, Keyser, and French Creek the proportion transforming the first season was so great as to insure nearly a full second brood of larvæ, while at Hagerstown and Pickens the large proportion wintering would indicate only a partial or scant second brood.

Where the banded orchards were bearing a full crop of fruit and other conditions were favorable for normal development of the larvæ, the relative sizes of the first-brood and second-brood band collections support the conclusions to be drawn from the data given in the table.

EFFECT OF DIFFERENCES IN ALTITUDE AND LATITUDE UPON THE DEVELOPMENT OF THE CODLING MOTH.

The stations at which the codling-moth rearing work reported in this paper was conducted comprise a range in altitude of 3,100 feet and in latitude of practically 1° 40′, or about 115 statute miles. In correlating the data from the various stations an effort has been made to determine whether or not definite differences in altitude and latitude have a corresponding and constant effect on the time of metamorphic changes in this species of insect. The results indicate

that the codling moth in its development is so responsive to transient weather conditions and other local disturbing factors that the time of appearance of a certain brood in one locality can not be determined with certainty by any mathematical calculation based on the known time of appearance of the same brood in another locality of a known difference in altitude or latitude. It is probable that local differences in humidity, susceptibility to sudden changes in temperature as effected by topography, and, possibly, soil conditions, are more or less direct factors influencing the time of developmental changes in the insect.

In Table XL the results of these observations are given. In this table use is made of the law laid down some years ago by Dr. A. D. Hopkins that in phenological phenomena a fourth of a degree of latitude, or 100 feet in altitude, is equal to one day of time. The table shows that in this particular case the law does not apply. Charlottesville, being at the lowest altitude and the most southerly of the stations, is taken as a base and the other points considered in their relation thereto. In considering this table it should be borne in mind that data were collected but twice a week and that the dates given for the first appearance of the insect in its various stages may be from one to three days later than the actual occurrence. Differences in latitude that are equivalent to less than half a day are not considered; those equivalent to more than half a day are counted as full days.

TABLE XL.—*Effect of differences in altitude and latitude on the time of appearance of spring-brood and first-brood codling moths and first-brood larvæ.*

Locality.	Year.	Date of emergence of first spring-brood moths.	Date of first larvæ collected under bands.	Date of emergence of first-brood moths.	Elevation above sea level.	Elevation above Charlottesville.
					Feet.	*Feet.*
Charlottesville, Va.	1912	May 7	June 6	June 20	400	.....
	1913	Apr. 18	June 5	June 14	400	.....
Greenwood, Va.	1912	May 8	June 6	June 23	900	500
	1913	.....	.....	.....	.....	.....
Hagerstown, Md.	1912	May 30	June 29	July 13	500	100
	1913	May 15	June 27	July 8	550	150
Winchester, Va.	1912	May 22	June 19	July 9	750	350
	1913	May 6	June 17	June 30	750	350
Fishersville, Va.	1912	May 18	June 11	July 2	1,500	1,100
	1913	May 3	June 14	.....	1,500	1,100
French Creek, W. Va.	1912	May 13	June 24	July 20	1,600	1,200
	1913	May 6	July 5	July 23	1,600	1,200
Pickens, W. Va.	1912	June 13	July 31	Aug. 20	3,500	3,100
	1913	June 24	.....	.....	.....	.....

TABLE XL.—*Effect of differences in altitude and latitude on the time of appearance of spring-brood and first-brood codling moths and first-brood larvæ*—Continued.

Locality.	Year.	Distance north of Charlottesville.		Number of days later than Charlottesville according to law of latitude and altitude.	Actual number of days later than Charlottesville.		
		Degrees and minutes.	Miles.		First spring-brood moths.	First larvæ under bands.	First summer-brood moths.
		° ′					
Charlottesville, Va.	1912						
	1913						
Greenwood, Va.	1912	0 4	5	5	1	Same day	3
	1913						
Hagerstown, Md.	1912	1 40	115	7	23	23	23
	1913			7	27	22	24
Winchester, Va.	1912	1 10	80	8	15	13	19
	1913			8	18	12	16
Fishersville, Va.	1912	0 4	5	11	11	5	12
	1913			11	15	9	
French Creek, W. Va.	1912	0 50	60	15	6	18	30
	1913			15	18	30	39
Pickens, W. Va.	1912	0 40	45	34	37	55	61
	1913			34	67		

RELATIVE NUMBERS OF LARVÆ ASCENDING AND DESCENDING THE TREES.

In 1911 several trees in a number of orchards were banded around the trunks and also around the bases of the larger branches. The lower bands were used to secure larvæ that had dropped with the infested fruit and ascended the trunk to spin up, and the upper bands were used for those that left the fruit before it dropped and descended toward the trunk for the same purpose. The following table shows the relative number of larvæ secured under the two sets of bands in the six orchards. In considering Table XLI due allowance should be made for an unknown number of larvæ that crawled across the bands or that spun up under the bark before reaching the bands.

TABLE XLI.—*Relative numbers of codling-moth larvæ collected from bands around the trunks and bases of branches, season of 1911.*

Locality.	Number of larvæ collected.			Per cent.	
	On trunk.	On branches.	Total.	On trunk.	On branches.
Hagerstown, Md.	543	602	1,145	47.42	52.58
Smithsburg, Md.	179	619	798	22.44	77.56
Hancock, Md.	75	91	166	45.18	54.82
Fishersville, Va.	96	68	164	58.54	41.46
French Creek, W. Va.	146	96	242	60.33	39.67
Pickens, W. Va.	29	30	59	49.15	50.85
Total.	1,068	1,506	2,574	41.49	58.51

SEASONAL EFFECT OF WEATHER CONDITIONS ON THE DIFFERENT STAGES OF THE CODLING MOTH.

The beginning of emergence of the spring-brood codling moths varies greatly from season to season, depending in any given year upon the temperature conditions that prevail during March, April, and May.

It will be noted, however, that in spite of the wide variation in the time of emergence of the spring-brood moths in 1912 and 1913 there was a tendency for the later stages of the insect to appear at more nearly the same periods both years. This is probably due to an equalization of midsummer weather conditions subjecting the later stages of the insect to the influences of a more constant seasonal temperature factor. At Winchester, where the codling moth was under closer observation than at other points, we find that while spring-brood moths emerged at least 10 days later in 1912 than in 1913, the second-brood larvæ began entering the fruit at practically the same time both years.

Hammar,[1] in his report on the codling moth in Pennsylvania, gives the following in his general summary:

> The time of the emergence of the spring brood of the moths is variable under different seasonal conditions and depends largely upon the relative lateness of the spring.
>
> The time of emergence of the summer brood, or first brood, of moths is fairly constant and generally commences about the 1st of August.

From the results of the band records and rearing work of 1912 and 1913 it would seem, therefore, that in all except very unusual seasons we may expect the feeding of second-brood larvæ to begin in the different sections about as follows: Charlottesville, Va., July 1; Fishersville, Va., July 10; Winchester, Va., July 15; Hagerstown, Md., July 25.

CANNIBALISM AMONG CODLING-MOTH LARVÆ.

During the progress of these studies it was noticed frequently that when a collection of codling-moth larvæ was confined in a rearing jar a considerable loss in their numbers from cannibalism was likely to occur. This habit, of the stronger larvæ devouring their weaker fellows, has been commented on by Hammar.[2] He states that cannibalism among the larvæ probably takes place also under normal conditions. In the jars the loss from this cause during the present investigations was frequently sufficient to amount to a considerable factor in influencing the number of moths to appear later.

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[1] Hammar, A. G. The codling moth in northwestern Pennsylvania. U. S. Dept. Agr., Bur. Ent., Bul. 80, Pt. VI, p. 111, 1910.

[2] Hammar, A. G. Life-history studies on the codling moth in Michigan. U. S. Dept. Agr., Bur. Ent., Bul. 115, Pt. I, p. 1–86, 1912. See p. 83.

NATURAL ENEMIES.

PREDACEOUS INSECTS.

It seems probable that many codling-moth larvæ, after leaving the fruit, are caught and destroyed by ants. A small red ant (*Solenopsis molesta* Say) was frequently met with on the bark of apple trees and under the bands engaged in killing and devouring the larvæ. Colonies of these ants that had their homes in the vicinity of banded trees seemed to form a habit of visiting the bands to obtain food. The collections of larvæ from trees in several localities were very considerably reduced in numbers from this cause. *Lasius niger* L. var. *americana* Emery, a species less abundant about the trees than the other, was also found killing the larvæ. These ants were determined by Prof. W. M. Wheeler.

Several species of beetles were found to be predatory on the larvæ and pupæ at the various stations. The most abundant of these was *Tenebroides corticalis* Melsh., both the larvæ and adults of which were frequently found under the bands devouring the larvæ and pupæ. Another beetle, *Hololepta lucida* Lec. (Pl. I, fig. 2), was found at Winchester with a codling-moth larva in its jaws. Two species of carabid beetles (*Calanthus opaculus* Lec. and *Platynus angustatus* Dej.) were common under the bands but were not observed to be feeding on the codling-moth larvæ. These beetles were determined by Mr. E. A. Schwarz, of the Bureau of Entomology. A coleopterous larva, which was determined as a species of Telephorus by Mr. H. S. Barber, was observed in the act of eating a codling-moth larva at Hancock in 1911.

HYMENOPTEROUS AND DIPTEROUS PARASITES.

Six species of hymenopterous parasites were reared from the codling-moth larvæ in the jars. Of these, *Ascogaster carpocapsæ* Vier. (Pl. I, fig. 1) was found at Winchester, Hagerstown, Smithsburg, Keyser, and French Creek, and outnumbered all others. An undetermined secondary parasite was found to be destroying this species in considerable numbers at Keyser in 1911. *Itoplectis marginatus* (Prov.) (fig. 23) occurred at Greenwood, Hagerstown, Winchester, and French Creek. A female of this species was observed on the trunk of an apple tree at French Creek ovipositing in a larva that had spun up under a scale of bark. *Macrocentrus* sp.[1] was reared at Greenwood in July, 1911; *Meteorus* sp.,[2] at French Creek in July, 1913; (*Microdus*) *Bassus*, n. sp. (Pl. I, fig. 4), at Smithsburg in July, 1911; and *Phanerotoma tibialis* Hald. at Charlottesville in 1911. The last species was determined by Mr. H. L. Viereck and the others by Mr. R. A. Cushman, of the Bureau of Entomology.

[1] Quaintance No. 7457. [2] Quaintance No. 7569.

A dipterous parasite, reared from codling-moth larvæ at Keyser in 1911, was determined by Mr. W. R. Walton, of the Bureau of Entomology, as (*Hypostena*) *Tachinophyto variabilis* Coq. (Pl. I, fig. 3). Only a few specimens of this species were obtained.

HAIRWORM PARASITES.[3]

Hairworm parasites of the codling moth (Pl. I, figs. 5, 6) were found at Greenwood, Keyser, and French Creek, being abundant in the second-brood larvæ at the latter place in 1911. These parasites were within the bodies of the codling-moth larvæ at the time collections

FIG. 23.—*Itoplectis marginatus*, a parasite of the codling moth. Enlarged. (Original.)

were made from the bands and usually issued from their hosts 10 days or 2 weeks after the larvæ were placed in the rearing jars. Occasionally dead larvæ, surrounded by a mass of dead hairworms, were found under the bands, and in a few cases the hairworms were found within apples borne by the banded trees. It was evident that infestation occurred at an early stage in the larval development and that all infested individuals died as full-grown larvæ. Most of the parasitized larvæ died within 10 days after being placed in the rearing jars.

The hairworms were from 2½ to 5 inches in length, and three or four were frequently observed to inhabit one larva. In leaving the host they passed through the anal opening or broke through the

[3] *Mermis* sp. Material was referred to Dr. B. H. Ransom, of the Bureau of Animal Industry, but as the specimens were all immature, they could not be determined specifically.

skin at some other point. After freeing themselves from the host, all that were observed writhed about actively for a few minutes and then died. Many of the hairworms did not escape from the codling-moth cocoons, but were found, at the time of the regular examinations of the jars, knotted together and dead, beside the flattened and shriveled larval remains. Table XLII shows the extent of parasitization at French Creek in 1911.

TABLE XLII.—*Extent of parasitization of codling-moth larvæ by hairworms at French Creek, W. Va., in 1911.*

Date larvæ were collected.	Number of larvæ collected.	Number of larvæ parasitized.	Per cent parasitized.
June 26	139	0	.....
July 3	68	0	.....
July 14	48	6	12.50
July 24	24	1	4.17
Aug. 4	14	3	21.43
Aug. 15	51	7	13.72
Aug. 23	34	11	32.35
Sept. 2	36	23	63.90
Sept. 13	43	21	48.84
Sept. 19	23	10	43.48
Oct. 3	22	6	27.27
Total	502	88	17.53

SUMMARY.

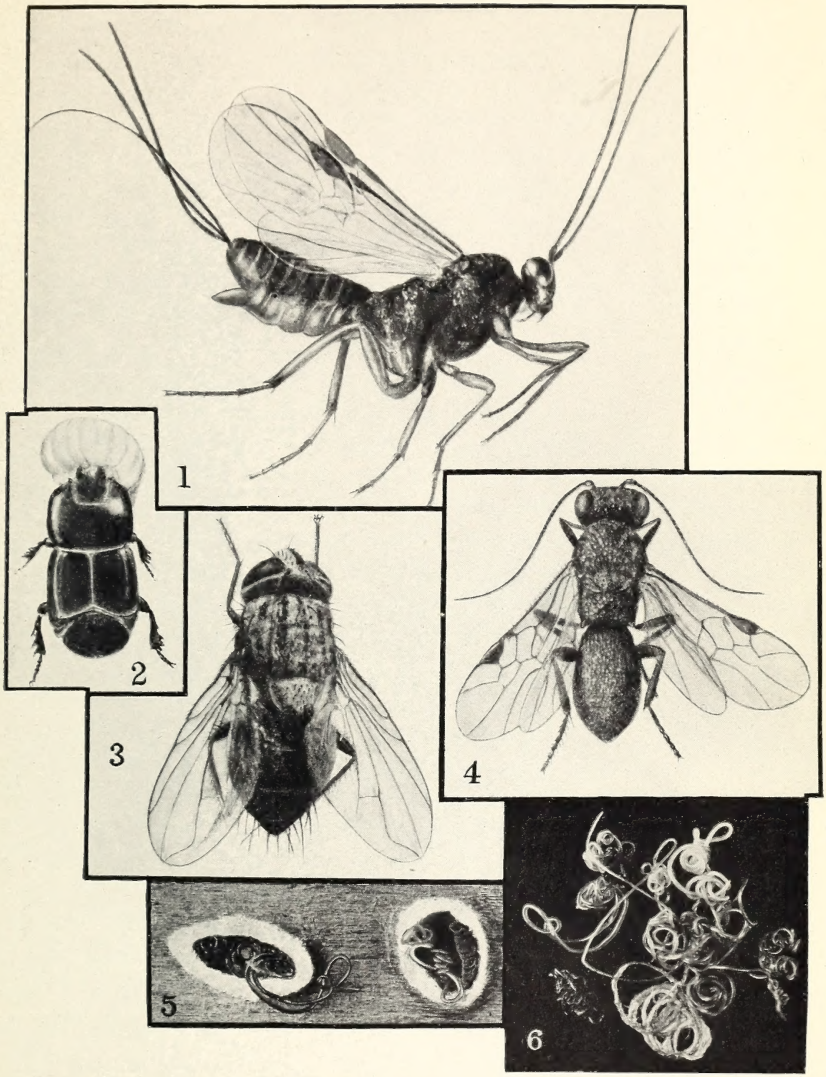
The foregoing account of the codling moth is based upon band-record studies conducted in 1911, 1912, and 1913 in several different localities of Virginia, West Virginia, and Maryland.

The stations at which the investigations were conducted comprise a difference in latitude of about 1° 40′ and in altitude of about 3,100 feet. The most southerly and least elevated station was at Charlottesville, Va., the most northerly at Hagerstown, Md., and the one at highest elevation at Pickens, W. Va.

The chief features of the investigations consisted of banding suitable apple trees with strips of burlap, collecting at regular periods the larvæ that went beneath the bands to spin up, and rearing these larvæ in jars kept in the localities where the larvæ were collected. Examinations of the bands and rearing jars were made every week or ten days in 1911 and twice a week in 1912 and 1913. No detailed life-history studies were attempted.

During a single year the codling moth, in the region covered by the present studies, produces one full brood of larvæ and a partial second brood, the size of the second brood depending more or less on the latitude and altitude of the locality.

The studies show a marked difference in the time of appearance of the different broods in different localities. Charlottesville gave the earliest records for practically all broods and Pickens the latest.



NATURAL ENEMIES OF THE CODLING MOTH (CARPOCAPSA POMONELLA).

Fig. 1.—*Ascogaster carpocapsae.* Fig. 2.—*Hololepta lucida* devouring codling-moth larva. Fig. 3.—(*Hypostena*) *Tachinophyto variabilis.* Fig. 4.—(*Microdus*) *Bassus* n. sp. Fig. 5.—Codling-moth larvæ killed in cocoons by hairworms (*Mermis* sp.). Fig. 6.—Mass of hairworms (*Mermis* sp.) taken from rearing jar, French Creek, W. Va. (Original.)

There seems, however, to be no constant rate of difference between the earlier and later localities. This seems to be largely due to the responsiveness of the species during its metamorphic changes to local and transient weather conditions.

During the time of the investigation the first-brood larvæ began entering the fruit at Charlottesville from April 28 to May 15, and second-brood larvæ from June 25 to July 1. At Pickens first-brood larvæ began entering the fruit from June 20 to July 1, and second-brood larvæ about August 10. Between these two localities there is a greater difference in the time of the regular periodical changes of the insect that occur late in the season than of those that occur early in the season. This is probably due to the cumulative retarding effect of the more frequent unfavorable weather conditions at the higher point.

For any given locality the variation in the time of appearance of spring broods in different years is greater than that of corresponding summer and fall broods of the same years.

Records of the numbers of larvæ collected from trees on which bands were placed around the trunks and also around the bases of the larger branches indicate that 41.49 per cent drop to the ground and then ascend the trunk to pupate and 58.51 per cent crawl down the branches from the infested fruit to pupate.

Where a collection of larvæ is confined in one jar there is apt to be a considerable loss due to cannibalism. It is probable that the weaker larvæ are sometimes devoured by their fellows under normal conditions.

Two specimens of ants (*Solenopsis molesta* Say and *Lasius niger* L. var. *americana* Emery) were found in several localities devouring codling-moth larvæ. Larvæ and adults of the beetle *Tenebroides corticalis* Melsh. were found frequently feeding on codling-moth larvæ and pupæ. Six species of hymenopterous and one of dipterous parasites were reared in the jars. Of these the most destructive to the codling moth were *Ascogaster carpocapsæ* Vier. and *Itoplectis marginatus* Prov. Hairworm parasites (*Mermis* sp.) were abundant in one locality and very materially reduced the number of wintering larvæ in the year 1911.

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